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WEEKLY 30 July 2022

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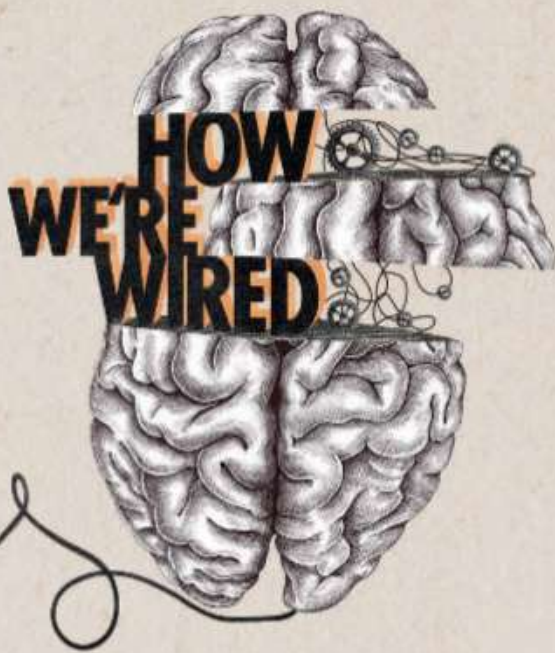
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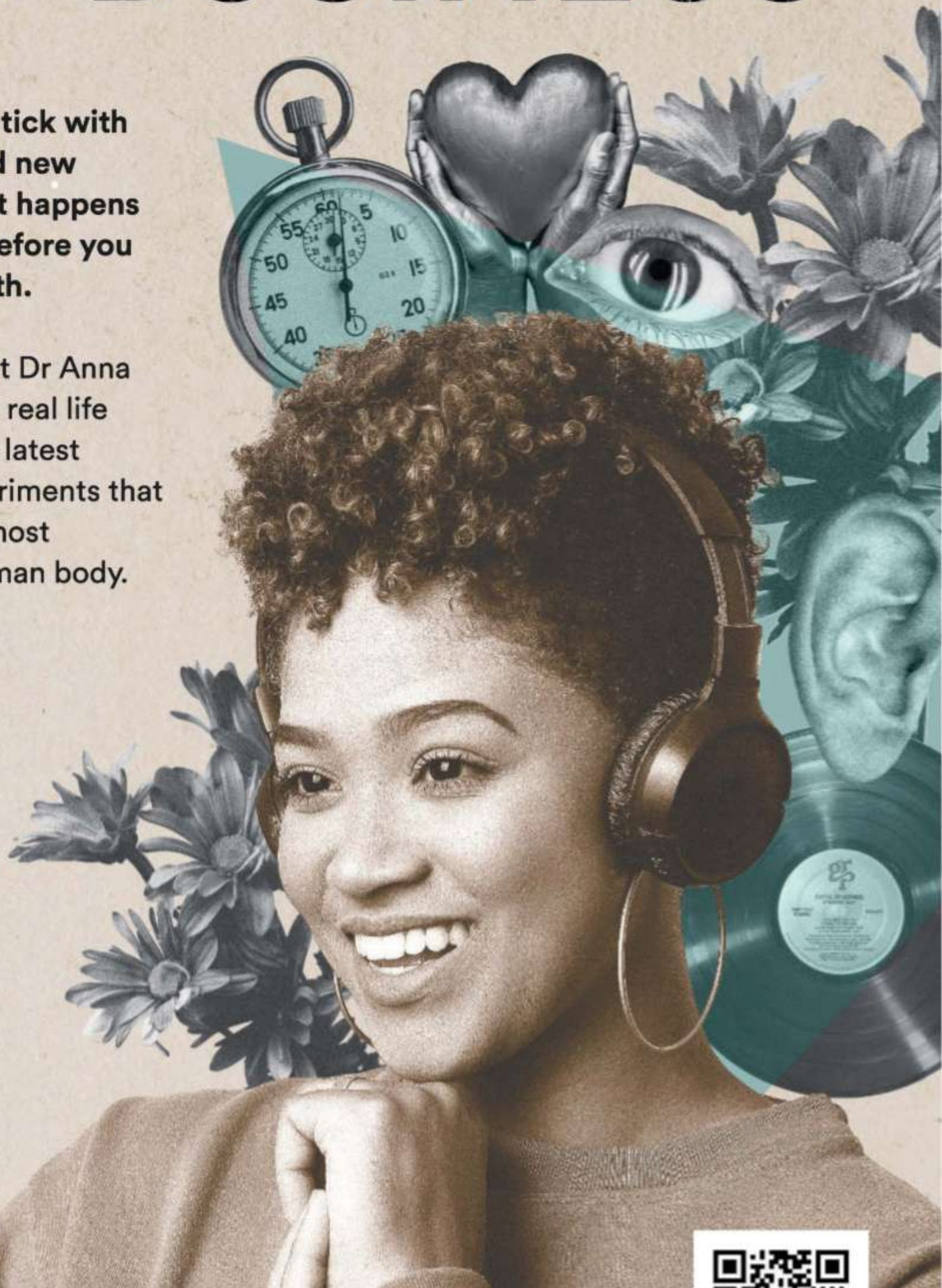
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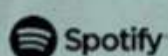
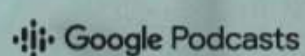
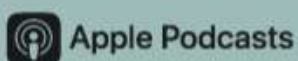
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An inventory of the universe, from rogue planets to the cosmic web



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Greener Living: Your guide to climate change and leading a more sustainable life

The world's climate is changing. It isn't too late to reduce your impact on global warming through green living, however. This CPD-accredited course will arm you with the knowledge to implement simple changes to your life that will help lessen your environmental footprint and let you live more sustainably.

academy.newscientist.com

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For the first time at our event in London, New Scientist Live has a dedicated day just for schools. We have a packed programme of engaging talks and a show floor full of interactive demonstrations, all dedicated to bringing science to life. Visit with your class at London ExCel on 7 October.

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Podcast

Weekly

Following record temperatures in the UK, the team members are hot and bothered and discuss how people can prepare for more extreme weather events. They also talk about what China is planning to do onboard its new space station. Plus, by converting astronomical data into music, we can now hear what a black hole might sound like. The team shares two beautiful pieces composed for an immersive new production called *Black Hole Symphony*.

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Academy



DEEPOOL BY PLAINPICTURE/PLATTFORM

Reuse, recycle What are the best ways to live more sustainably?

Newsletter



ALEX MUSTARD/NATUREPL.COM

Safely does it How to enjoy coastal wildlife without doing any harm

Video

Bison biodiversity

Four European bison have been released into ancient woodland in south-east England, part of a rewilding project. The aim is to explore the potential benefits these large animals can have on woodland habitats. It is the first time bison have been introduced to the UK. *New Scientist* met the team behind the project, including the UK's first bison rangers.

youtube.com/newscientist

Newsletter

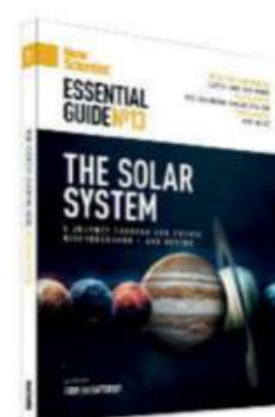
Wild Wild Life

As summer vacations begin in the northern hemisphere, news and digital director Penny Sarchet is looking at coastal wildlife and what you can do to enjoy it without causing any harm. Plus, she introduces a newly identified, mysterious sponge, and discusses penguins that change their accents.

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Video

“Bison do things that no other animals do, like creating little dust baths”



Essential guide

How does the sun work? Why does the moon matter? Is there alien life? Knowledge of our solar system has reached new heights – but there is still much to discover about our nearest planets and the worlds beyond. Explore more in the latest *New Scientist Essential Guide*.

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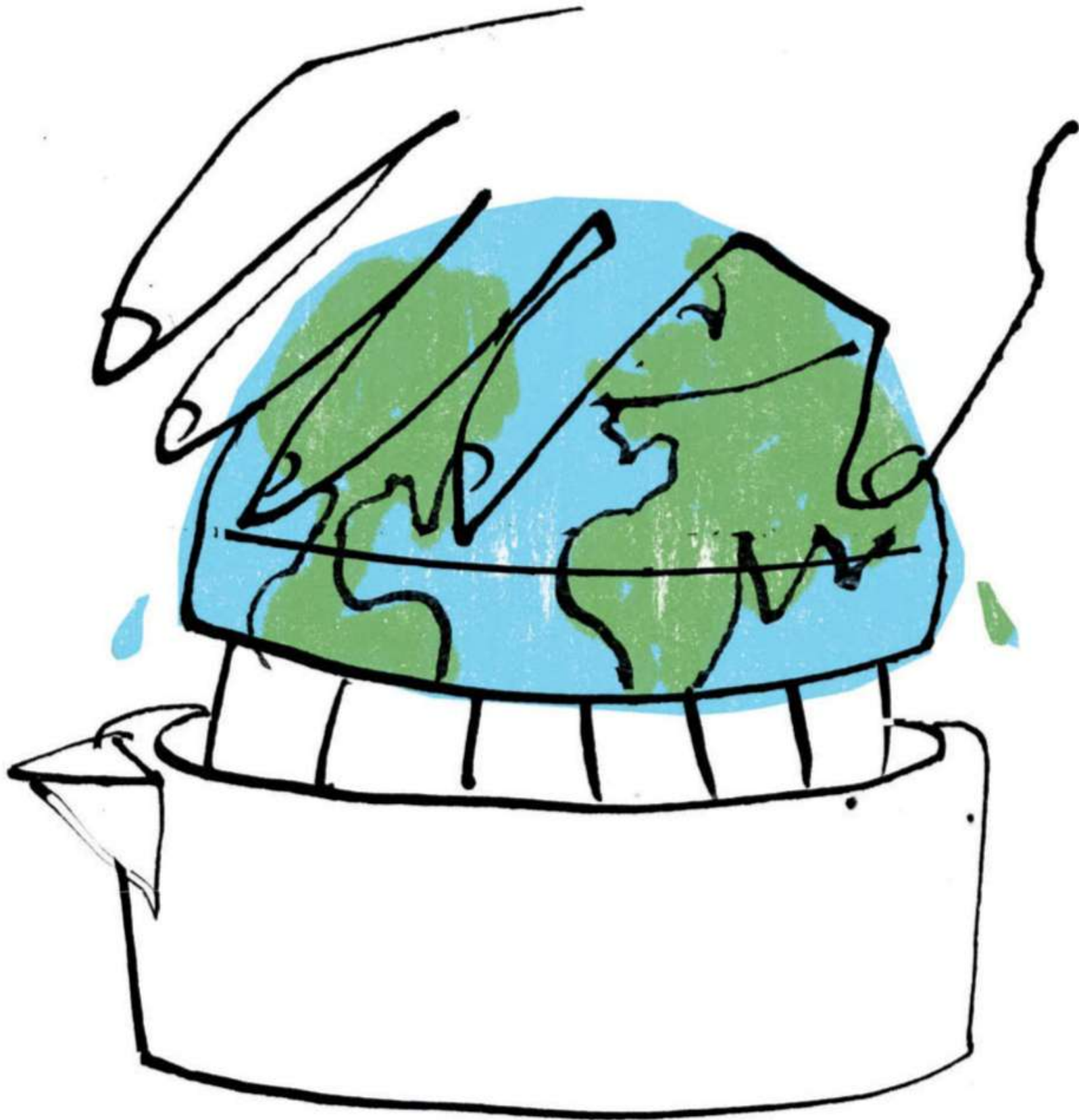


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Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

Your Will can fund the rational response to health challenges that medical science provides.

"As scientists, our duty is to secure the future of research for the generations that follow."

Professor Fiona Watt, Patron of the Medical Research Foundation and Director of the European Molecular Biology Organization.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that



research forward, are the key to meeting those challenges for years to come.

But many of these scientists rely on the generosity and foresight of fellow members of the public – people like you, who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact

on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine
CBE MD PhD FMedSci
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Monkeypox failings

More could have been done to prevent a global emergency

THE World Health Organization has finally sounded its most serious alarm over the spread of monkeypox, declaring it a “public health emergency of international concern”, just as it did for covid-19 in 2020.

Many researchers think this decision should have been taken a month ago when the WHO first considered it. The disease is spreading rapidly around the world, with more than 16,000 cases confirmed so far this year (see page 7).

But the real issue isn’t this delay. It is that we have had decades to stop this outbreak happening and failed to do so.

We have known monkeypox can jump to people since the 1970s. In particular, after an outbreak in Nigeria in 2017, there were warnings that human-to-human transmission seemed to be increasing.

Throughout this period, we have had smallpox vaccines and treatments that also work for monkeypox, but they haven’t been used. There has also been plenty of time to develop more effective treatments and vaccines specifically for monkeypox, but it didn’t happen.

“We need to do more to ensure other emerging diseases never go global”

Why? Because almost all the cases were in Black people in low-income countries in certain parts of Africa.

There is a moral imperative for richer nations to help tackle preventable diseases in poorer places. It is also in the self-interest of richer countries to do so,

because infectious diseases don’t care about borders. An emerging disease anywhere has the potential to become a problem everywhere.

Having missed the opportunity to prevent this monkeypox outbreak in the first place, the response in many countries has also been inadequate. For instance, in the US there have been major issues with testing and with the roll-out of vaccines – much as there were with the coronavirus.

All this is alarming, not just because efforts to halt this outbreak appear to be failing. Sadly, it also suggests the world hasn’t learned much from the covid-19 pandemic, in particular the importance of acting early. There are other emerging diseases around the world. We need to do more to ensure they never go global. ■

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Sales director Justin Viljoen

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Recruitment advertising

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CONTACT US

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General & media enquiries

UK Tel +44 (0)203 615 6500

Northcliffe House, 2 Derry Street, London, W8 5TT

Australia 58 Gipps Street, Collingwood, Victoria 3066

US PO Box 80247, Portland, OR 97280

UK Newsstand

Marketforce UK Ltd **Tel** +44 (0)33 0390 6555

Syndication

Tribune Content Agency **Tel** +44 (0)20 7588 7588

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One year print subscription (51 issues) UK £270

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Post New Scientist, Rockwood House, Perrymount Road, Haywards Heath, West Sussex RH16 3DH

© 2022 New Scientist Ltd, England. New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Precision Colour Printing Ltd



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REUTERS/EDUARDO MUNOZ

A monkeypox vaccination centre in New York

people required hospitalisation.

In the current outbreak, there have been five confirmed deaths from the disease in Africa so far, according to the WHO, although dozens more are suspected. There have been no deaths reported elsewhere.

Symptoms of monkeypox include fever, headaches, fatigue and a rash. The rash typically develops on the face first and then on other parts of the body. The WHO reports that the UK is also planning to list inflammation of the lining of the rectum as a symptom.

Designating monkeypox as a global emergency means that the outbreak is unprecedented, affects multiple countries and requires a coordinated international response, said Hugh Adler at the Liverpool School of Tropical Medicine in the UK, in a statement to the UK's Science Media Centre.

"Naming this a public health emergency of international concern adds political weight and urgency to this situation," he said. "It ensures that this outbreak can be prioritised."

Countries already experiencing monkeypox cases have been told by the WHO to raise awareness among those most at risk and to increase their efforts to identify and isolate people with the disease. These places should also step up vaccination programmes, they have been told.

Imvanex, also known as Jynneos in the US, is a smallpox vaccine that is also effective against monkeypox. It was approved for use against monkeypox in the European Union this week. People most at risk of infection in the UK have been offered the vaccine and the UKHSA has recently secured another 100,000 doses of the jab. ■

Diseases

Monkeypox emergency

As cases surge, the WHO has raised its alert level and said nations must do more to combat the disease, reports **Jason Arunn Murugesu**

THE World Health Organization (WHO) has declared monkeypox a global health emergency. It announced on 23 July that the spread of the viral infection constitutes a "public health emergency of international concern", its highest alert level, putting it on a par with the coronavirus pandemic and global efforts to eradicate polio.

The decision follows more than 16,000 reported cases of monkeypox across 75 countries this year. There have been more than 2000 in the UK so far, according to the UK Health Security Agency (UKHSA).

But the WHO panel behind the decision was split on whether to declare monkeypox a global

emergency, with director-general Tedros Adhanom Ghebreyesus acting as a tiebreaker. Some members of the panel argued that the disease isn't so severe and that case numbers don't seem to be rising exponentially, while others countered that confirmed case numbers are probably an underestimate and that the disease requires a coordinated international response.

Monkeypox can affect anybody, but the vast majority of cases have been in men who have sex with men, according to the WHO. It reported that 99 per cent of cases have been in this group in the UK, US, Canada and Spain, the countries that have provided the most data to the WHO. The disease

is more likely to occur in people who have had multiple sexual partners recently.

One way monkeypox is thought to spread is through skin-to-skin contact, including sex, but until this year, there was no indication that this form of transmission was particularly prominent.

"Declaring a public health emergency adds political weight and urgency to this situation"

A study published last week, which analysed monkeypox cases in 16 countries, found that just 0.8 per cent of cases were probably caused by non-sexual close contact. The study also found that 13 per cent of

Climate change

'Net-zero' aviation won't be enough

Efforts to make flying greener mostly only account for carbon dioxide emissions

Adam Vaughan

FLIGHTS will endanger the Paris climate agreement's goals if efforts to achieve net-zero aviation don't account for the warming effect of streaks of clouds created by planes, a study has found.

The research comes after the UK government announced its Jet Zero Strategy on 19 July, with a target of cutting carbon emissions from flights to net zero by 2050 (see page 23 for more on UK plans).

Nicoletta Brazzola at ETH Zurich in Switzerland and her colleagues found that even if such efforts to reduce emissions succeed, the world's aviation sector could increase average temperatures by between 0.1°C and 0.4°C. The world has already warmed by 1.1°C since the industrial revolution, so the extra warming could compromise the Paris deal's aim of holding temperature rises to 1.5°C, says Brazzola's team.

The warming comes from the ways flights heat the atmosphere beyond the carbon dioxide emitted by burning jet fuel, which is the only impact currently counted by international and most national efforts to

decarbonise aviation. The main one of these non-CO₂ effects is the contrails that form because of the soot, aerosols and water vapour released by aircraft engines.

"We found the mitigation efforts needed to get aviation to a place where it's compatible with the Paris agreement are enormous," says Brazzola.

Her team explored future scenarios of demand for flights,

Planes warm the planet by creating contrails as well as by directly emitting carbon

technologies to power them and how much CO₂ would need to be removed from the atmosphere by trees or machines to hit net zero. "Without a very strong reduction in demand and without very rapid, almost infeasible switches to clean technologies, we would in all cases need to deploy carbon removal to a very large extent," she says.

The team's modelling suggests that failing to account for aviation's non-CO₂ effects would ignore 90 per cent of future flights' contribution to climate change (*Nature*

Climate Change, doi.org/h567).

"This new study makes a compelling case for moving away from carbon-neutral aviation as the main policy goal, and focusing on climate-neutral aviation instead," says Paul Williams at Reading University, UK.

The study indicates that new fuels and flight technologies, from hydrogen to batteries, will need to be developed and deployed rapidly to stand a chance of reaching climate neutrality. It also suggests that the aviation sector's short-term carbon-offsetting plan for reducing its impact on climate change won't be enough.

Brazzola's team found that even with a moderate increase in demand for flights, the status quo of jet fuel and offsetting would require an area the size of Germany to be planted with trees to compensate for planes' effects.

"Continuing flying with passenger jet fuels and offsetting carbon removal is a very unviable pathway," says Brazzola. Reaching climate neutrality will require curbing the world's appetite for flights too, she adds. ■



SHUTTERSTOCK/JOE PHOTO

Health

We don't actually know what 'growing pains' are

THE term "growing pains" is often used to refer to sore or aching limbs in children. Yet, there is no clear definition of what growing pains are, and now it looks like they may not be related to growth at all.

A recent analysis of studies about growing pains notes that 93 per cent make no mention of how the symptoms of bone or muscle pain are related to growth.

"Kids and teens are being told

they have growing pains, but that is inaccurate based on our findings," says Mary O'Keeffe at the University of Sydney in Australia, who led the review. Most children diagnosed with growing pains are told the pain will subside with age and that they can take children's ibuprofen or paracetamol (acetaminophen) to manage the discomfort if needed.

"If a health professional is giving a diagnosis, it needs to be based on sound evidence. They need to be sure that growing is the cause, but we don't know this," says O'Keeffe.

To investigate, she and her colleagues identified 147 studies

that mentioned growth or growing pains in adolescents. They looked at how each study defined growing pains based on the type, location, duration, timing, severity and age of onset of pain, as well as the pain's relationship with activity and physical examinations.

They found contradictions in multiple areas. For example, 14 per cent of studies claimed that growing pains are persistent while 5 per cent

"Kids and teens are being told they have growing pains, but that is inaccurate based on our findings"

said they aren't. Only seven studies said the condition could be due to growth, and two said the pains had nothing to do with growth.

The closest the research came to consensus was on pain location: 50 per cent of studies concluded that growing pains primarily affect the legs. Others identified the arms, back, groin or shoulders as the main pain locations (*Pediatrics*, DOI: 10.1542/2020-052578).

"If I was a doctor, I would stop using the term, as currently it doesn't seem to serve a purpose," says O'Keeffe. ■

Grace Wade

JWST spots oldest ever galaxy...

Jonathan O'Callaghan

JUST weeks into its mission, the James Webb Space Telescope (JWST) has broken the record for the oldest galaxy ever observed by nearly 100 million years.

Seeing some of the most distant and earliest galaxies to form after the big bang 13.8 billion years ago is one of the key goals of JWST. When these emerged is currently unknown: the previous oldest identified galaxy, found by the Hubble Space Telescope, is called GN-z11 and dates back to 400 million years after the birth of the universe.

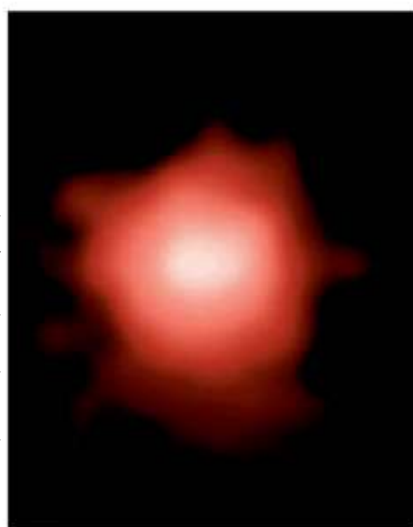
Rohan Naidu at the Harvard-Smithsonian Center for Astrophysics and his colleagues think they have already found an older one in a publicly released JWST data set called GLASS. Known as GLASS-z13, the galaxy dates back to just 300 million years after the big bang. The team also found a second galaxy, GLASS-z11, of a comparable age to GN-z11 (arxiv.org/abs/2207.09434).

"We found two compelling candidates for extremely distant galaxies," says Naidu. "If these galaxies are at the distance we think they are, the universe is only a few hundred million years old at that point."

The two galaxies appear to have grown the equivalent mass of a billion suns since they began forming. That is something we would expect for galaxies that have been developing for around 500 million years, says the team, possibly hinting that stars formed more rapidly than we thought in the early universe.

Both galaxies are very small, GLASS-z13 being only about 1600 light years across and GLASS-z11 about 2300 light years. By comparison, our Milky Way is some

NAIDU ET AL., POESCH, T. TREU, GLASS-JWST, NASA/CSA/ESA/STSCI



GLASS-z13 dates back to 300 million years after the big bang

100,000 light years across.

Gabriel Brammer at the Niels Bohr Institute in Denmark, part of the GLASS team and a co-discoverer of GN-z11, says that further analysis will be needed to confirm the distance to the two galaxies. Only JWST can do that work. "They're very convincing candidates," he says. "We were pretty confident that JWST would see distant galaxies. But we're a little bit surprised how easy it is to detect them."

A separate team led by Marco Castellano at the Astronomical Observatory of Rome in Italy also found that GLASS-z13 was the earliest known galaxy (arxiv.org/abs/2207.09436).

JWST should make discoveries like this regularly. Longer hunts for ancient galaxies should be able to probe much further, perhaps to less than 200 million years after the big bang, when some of the first galaxies and stars in the universe are thought to have formed.

"How early does star formation start in the universe?" asks Naidu. "It's one of the last major unknowns in our broad timeline of the universe." ■

...and a glut of Milky Way-shaped galaxies

Will Gater

ASTRONOMERS analysing some of the first scientific data released by the James Webb Space Telescope (JWST) have already seen something unexpected.

A deep view of the early universe appears to show a surprisingly high number of disc-shaped galaxies, rather than the large number of clumpy, irregular ones we thought would be there.

This suggests that the disc structures in certain galaxies, including the Milky Way, may have formed more rapidly than current theories predict.

Leonardo Ferreira at the University of Nottingham, UK, and his colleagues looked at galaxies within JWST's "deep-field" image of the galaxy cluster SMACS J0723.3-7327, which was first released to the public on 12 July. The researchers examined several hundred of these distant galaxies – which existed a couple of billion years after the big bang – by eye and with the aid of computers, in order to classify them into their different shapes.

Previous work using data from Hubble Space Telescope observations and computer modelling indicated disc-shaped galaxies should only account for about 5 per cent of the sample studied in this new JWST image.

50%

Proportion of disc-shaped galaxies seen by JWST

But the team actually found that roughly half the galaxies scrutinised were disc-shaped (arxiv.org/abs/2207.09428).

The result, if confirmed by further, more extensive, surveys as JWST gathers more data, could mean that the disc structure in galaxies we see around us today emerged far earlier than

astrophysicists imagined.

They thought this because disc shapes are generally believed to arise when galaxies have had a long time to settle down after an earlier, tumultuous period of collisions and mergers – one that is associated with irregular-shaped galaxies, the kind astronomers thought they would see more of.

That, says Ferreira, has "huge implications" for the models that astrophysicists currently use to explain how galaxies are born and evolve. "This is a clue already that something's off," he says.

There could also be wider implications for cosmological models of the expansion of the universe, dark matter and dark energy, which often include predictions for how galaxies evolve over time. "If the models can't predict the formation of galaxies, the models [are] not actually correct," says Ferreira.

Brooke Simmons at Lancaster University, UK, says this early result from JWST data is "really interesting work" that is "potentially going to hold up".

She suspects the reason NASA's newest space telescope, which detects in the infrared part of the spectrum, may be seeing the disc galaxies where Hubble wasn't able to spot them is that JWST not only observes at different wavelengths, but also has bigger optics.

"The mirror for JWST is two-and-a-half-times bigger than the mirror from Hubble," says Simmons. "So it's just a bigger light bucket, so you can get a really deep image much faster."

In order to confirm the new result, Simmons says astronomers will need to analyse light from the galaxies to see if they are spinning in the way discs are expected to rotate – something that should be well within the capabilities of JWST's instruments. ■

AI art tool covertly alters requests

Apparent efforts to improve the diversity of pictures created by artificial intelligence DALL-E 2 have been criticised for a lack of transparency, reports **Matthew Sparkes**

ARTIFICIAL intelligence firm OpenAI seems to be covertly modifying requests to DALL-E 2, its advanced text-to-image AI, in an attempt to make it appear that the model is less racially and gender biased. Users have discovered that keywords such as “black” or “female” are being added to the prompts given to the AI, without their knowledge.

It is well known that AIs can inherit human prejudices through training on biased data sets, often gathered by hoovering up data from the internet. For example, if most of the images of a doctor in an AI’s training set are male, then the AI will generally return male doctors when asked for an image of a doctor.

One way to avoid this is to use a diverse set of training data, but OpenAI seems to have taken a different approach, according to researchers who have uncovered evidence that DALL-E 2 silently and randomly adds extra words to prompts to increase diversity.

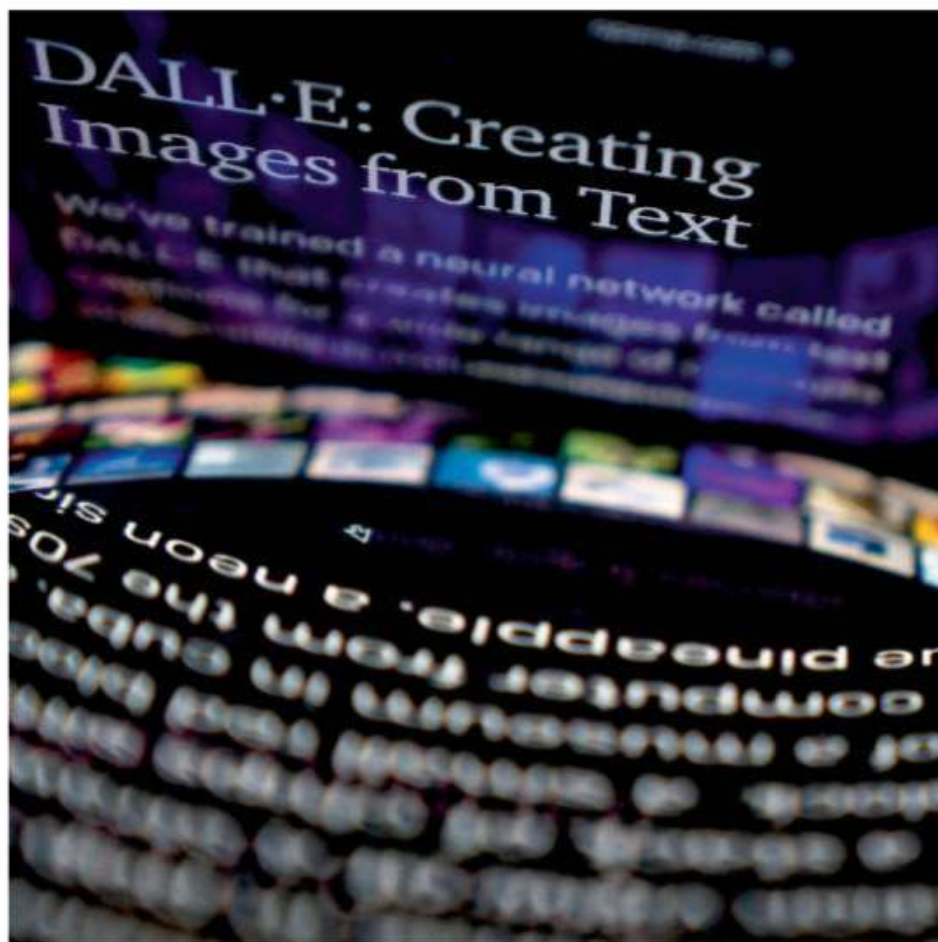
For instance, when Richard Zhang at Adobe Research asked DALL-E 2 to create an image of “a person holding a sign that says” it created an image of a Black woman holding a sign that says “BLACK”, suggesting that the full prompt used by DALL-E 2 was “a person holding a sign that says black”.

AI creations

When Zhang asked for “pixel art of a person holding a text sign that says”, DALL-E 2 created an image of a woman holding a sign that said “FEMALE” and when he asked for “pixel art of a stick figure person in front of a text sign that says”, DALL-E 2 output an image of a man with a caption below saying “BLACK MALE”.

More examples of similar

STEFANI REYNOLDS/AFP VIA GETTY IMAGES



DALL-E 2 is a powerful text-to-image generator tool made by OpenAI

results have been shared online recently, with many people suggesting that it pointed to OpenAI deliberately adding words to inputs in order to counteract inherent biases.

Jamie Simon at the University of California, Berkeley, says that machine-learning methods like those behind DALL-E 2 often do produce unusual or unexpected images, but that the unprompted text appearing in some images is surprising. “In my experience, it’s rare for generated images to include coherent text unless it’s in the prompt,” he says.

OpenAI has publicly announced an update to DALL-E 2 that makes it “more accurately reflect the diversity of the world’s population”, saying that internal tests had found that users were 12 times

more likely to say that images included people from diverse backgrounds after the update. Its previous version had caused some users to point out racial and gender bias, the company said.

But OpenAI gave no details in its blog post of the exact changes that had been made or how they worked. A subsequent blog post announcing the release of DALL-E 2

“AIs with potentially transformative impacts are being developed with quite a lot of secrecy”

to more users said that the feature “is applied at the system level when DALL-E is given a prompt about an individual that does not specify race or gender, like ‘CEO’”.

A spokesperson for OpenAI told *New Scientist* that prompts given to DALL-E 2 were modified if they were “underspecified”. If a prompt describes a generic person

and doesn’t specify what gender or race they should be, then DALL-E 2 will be specifically told to add a certain race and gender “with weights based on the world’s population”, said the spokesperson. The company declined to grant access to DALL-E 2 so that *New Scientist* could run its own tests.

Lack of transparency

Mhairi Aitken at the Alan Turing Institute in the UK says that the lack of transparency makes it hard for the public to assess the quality of models and to what extent they have inherited bias from online content.

“It shows the problems of a lack of transparency around how these models are designed and developed. These models, which are potentially going to have really fundamental impacts on society, potentially transformative impacts, are being developed with quite a lot of secrecy,” she says. “Without that transparency around how it’s actually been done, there’s always going to be speculation about what approaches have been taken and how things could be done better.”

Sandra Wachter at the University of Oxford says that problems with AI models exhibiting racist and sexist tendencies are a reflection of our society, and that while quick technical fixes can give the appearance of a solution, the real problem to be solved is in the culture that generated the training data. “They tried to solve it by using a tech approach,” she says of OpenAI’s update. “It’s a sticking plaster, it’s just making it seem less biased, but the social component is actually not changing at all.” ■

Technology

Robot learns social cues to feed people at appropriate times

Matthew Sparkes

ROBOTS that watch for social cues could feed people by gauging when they are ready for a mouthful. This may make it easier for people who can't feed themselves, such as those with tetraplegia, to socialise.

People who can't control their arms and legs can use commercial robotic arms to help them eat. These use set time intervals between mouthfuls or manual triggers, but they can be awkward in social settings and interrupt conversation. Now Jan Ondras at Cornell University in Ithaca, New York, and his colleagues have trained an artificial intelligence to pick up the social cues at meals via videos of 30 groups of three people eating together in a social setting.

The AI model learned to recognise the behaviour that the person taking a mouthful and their companions displayed before the act of eating, which the researchers say in their paper is a "delicate dance of multimodal signalling".

To put the model, called Social Nibbling Network (SoNNET), to the test, the team recruited 10 groups of three diners for trials with a commercially available robot arm. One person in each group was selected to constrain their arms and be fed by the robot.

The experiments used one of three strategies to initiate the robot to supply a mouthful of food: a set time interval; feeding a mouthful when the diner opened their mouth and kept it open as a cue; and SoNNET. The participants rated SoNNET as the best option.

Paralysis can have a devastating effect on people, says Brian Carlin at UK spinal injury charity Aspire, and being able to use devices like this to recover a sense of independence could be hugely beneficial.

"To give them that freedom and independence to undertake a normal daily activity is very powerful," he says. ■

Genetics

Gene-edited dogs created from cloned skin cells

Michael Le Page

TWO beagles have been born in South Korea from cloned skin cells altered by CRISPR gene editing. CRISPR-edited dogs have previously been created by altering fertilised eggs, but this is the first time they have been made by cloning.

Many pure-bred pedigree dogs have disease-causing mutations. Gene editing could be used to eliminate these without affecting other traits. The cloning approach has advantages over the editing-eggs one for this purpose, says Okjae Koo at biotech company ToolGen. "[It] is more reliable for generating various pure-bred, genome-edited dogs," he says.

The technique might also help us create therapies for some human diseases.

To create the cloned puppies, Koo and his colleagues first gene edited skin cells to mutate a gene called *DJ-1* and prevent the protein it codes for from being made. Mutations in *DJ-1* are associated with diseases such as Parkinson's, so studying dogs that lack the DJ-1 protein could help develop treatments for these conditions.

In addition to knocking out *DJ-1*, the team added several genes, including one for a fluorescent green protein called GFP. This was to help detect which cells had been successfully edited, but the team doesn't plan to add these genes in future studies, says Koo.

The team then placed these cells next to egg cells whose DNA had been removed. Pairs of skin cells and empty egg cells were fused together by short

3%

Proportion of implanted embryos that resulted in a live birth

pulses of electricity, and the resulting embryos implanted in a surrogate mother.

At the age of 22 months, the two dogs are healthy and don't have any abnormalities – although their skin does glow green in ultraviolet light. Since diseases linked to *DJ-1* are age-related, the dogs might develop issues as they get older (*BMC Biotechnology*, doi.org/h5wf).

Altogether, 68 embryos were transferred into six dogs,

resulting in the two puppies. That is a success rate of around 3 per cent – similar to that achieved by Lai Liangxue at the Guangzhou Institutes of Biomedicine and Health in China when his team created the first CRISPR-edited dogs, a feat they revealed in 2015.

Those dogs, called Tiangou and Hercules, are beagles that have more muscle mass than normal due to a gene deletion. "Both Tiangou and Hercules are fine," says Lai. His team has since created several other dogs using the same method, he says.

Lai says the cloning technique used by the team in South Korea does have advantages. When fertilised eggs are gene edited, the resulting animals are usually chimeras, meaning some of their cells are gene edited, but others aren't. Because of this, further breeding is needed to create dogs whose cells all have the desired change, says Lai. With the cloning technique, no further breeding is necessary.

Both Lai and Koo's teams are creating dogs for medical research. However, cloning is also increasingly being used to create copies of beloved pets that have died, using tissue samples taken soon afterwards.

In the US, a company called ViaGen has so far created about 1000 "cloned companion animals", a spokesperson told *New Scientist*. Cloning could be combined with gene editing to make these animals healthier. ViaGen doesn't currently offer any kind of genetic editing or modification, but hasn't ruled out doing so in the future. ■

Beagle puppies created in South Korea from cloned skin cells



OKJAE KOO/TOOLGEN

Space exploration

Science lab module joins China's Tiangong space station

Alex Wilkins

CHINA launched the second module of its Tiangong space station on 24 July, adding its first laboratory module to the station, after the 16-metre-long core module Tianhe launched in April 2021.

The new addition, which is called Wentian or “Quest for the Heavens”, was launched on a Long March-5B Y3 rocket from Hainan Island, located south-west of Hong Kong, at 2.22pm local time.

“As a major spacefaring nation, China has arrived,” says Quentin Parker at the University of Hong Kong. “It’s only the third nation after Russia and America to have a space station and this one is spanking new. It’s got all the latest technology.”

As well as having the ability to perform more advanced scientific experiments in microgravity than Tianhe, Wentian adds several key features to the station. These include a 5-metre-long robotic arm, large solar panels and an airlock, which will become the main entry and exit point for future vehicles and astronauts accessing the station. In addition,

Wentian has extra navigation and communication systems, as well as propulsion tools that can be used to reorient the station in case Tianhe’s systems fail.

Wentian – which measures about 18 metres long and 4 metres wide, similar to Tianhe – will also serve as additional crew quarters, doubling the station’s capacity from three to six astronauts.

Wentian has initially docked

with Tianhe on one end, but will later detach and reorient itself using the two modules’ robotic arms, reattaching to the side of Tianhe to form part of the station’s eventual T-shape. “That’s going to be quite interesting, but it’s the kind of thing that they will have tested a lot to be confident they can do it,” says David Brown at the University of Warwick, UK.

The three crew members currently in Tianhe will then enter Wentian, activating its various life-support systems and experiments. After Wentian is fully operational,

another laboratory module, Mengtian, will launch in October, marking the completion of the space station’s T-shape.

The frequency and variety of China’s recent space launches has surprised even seasoned observers. “China’s quietly now launching more rockets than anyone else into orbit,” says Parker. “It did it last year, it’s going to beat its own world record again this year. It’s got plans for a moon base and everything else. So you know, they’re quietly and methodically and carefully really going places in space.”

One reason for an increased focus in China on domestic space policy and experiments is because of the geopolitical difficulty of collaborating on US-led missions, such as the International Space Station, says Parker.

“If, for example, another country wants to conduct human space flight, or wants to put an astronaut into space, they don’t have to go through the US anymore,” says Christoph Beischl at the London Institute of Space Policy and Law. ■

The Wentian module blasts off on a Long March-5B Y3 rocket



LUO YUNFEI/CHINA NEWS SERVICE VIA GETTY IMAGES

Zoology

Hibernating beetles break down and regrow their muscles

SOME beetles can shed most of their muscle during the winter and rebuild it by spring without moving.

The Colorado potato beetle (*Leptinotarsa decemlineata*) can survive up to four months buried beneath the snow in Canada with temperatures dropping to -20°C. During hibernation, it slows its metabolism by as much as 90 per cent to save energy, but how it does this was poorly understood.

To investigate, Jacqueline Lebenzon at Western University in London, Canada, and her colleagues mimicked seasonal light and temperature changes in the lab and used an oxygraph to measure the amount of oxygen consumed by the insects’ mitochondria – the parts of cells that convert food into energy.

To their surprise, the oxygraph’s readings were zero. The researchers used microscopy to discover that there were no mitochondria to measure because the beetles had lost nearly all of them.

“It was just a really exciting discovery and a simple explanation

for why their metabolism was so low. I was banking on it being a little bit more complex,” says Lebenzon.

More surprisingly, the beetles had restored the mitochondria by the “spring” without eating or moving (*PNAS*, doi.org/gqh5bx).

Some insects, including moths and crickets, break down their flight muscles to save energy for reproduction, but they permanently lose the ability to fly.

“It was just a really exciting discovery and a simple explanation for why their metabolism was so low”

It is likely that the beetle can restore its flight muscles because it breaks down only the mitochondria but retains the nuclei of muscle cells and most of the protein, says Lebenzon. “We think that it would take a lot more energy to rebuild everything,” she says.

The beetles begin losing mitochondria weeks before hibernation and start producing them again a few weeks after becoming dormant.

Other insects lose flight muscles when hibernating, so could use the same process, say the researchers. ■
Luke Taylor

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Field notes Murujuga, Western Australia

Ancient Aboriginal art could reveal Australia's environmental past

Murujuga holds millions of engravings from at least 50,000 years ago – and could provide a glimpse into climate change, says **Alice Klein**



“ALL our stories are written on these stones,” says Corey Adams, a traditional Aboriginal custodian of the Murujuga land we are standing on in Western Australia. He is showing me around the densest collection of ancient rock art in the world – more than 2 million engravings, or petroglyphs, that his ancestors have created since becoming the first people to set foot in Australia. The collection has been added to for more than 50,000 years,

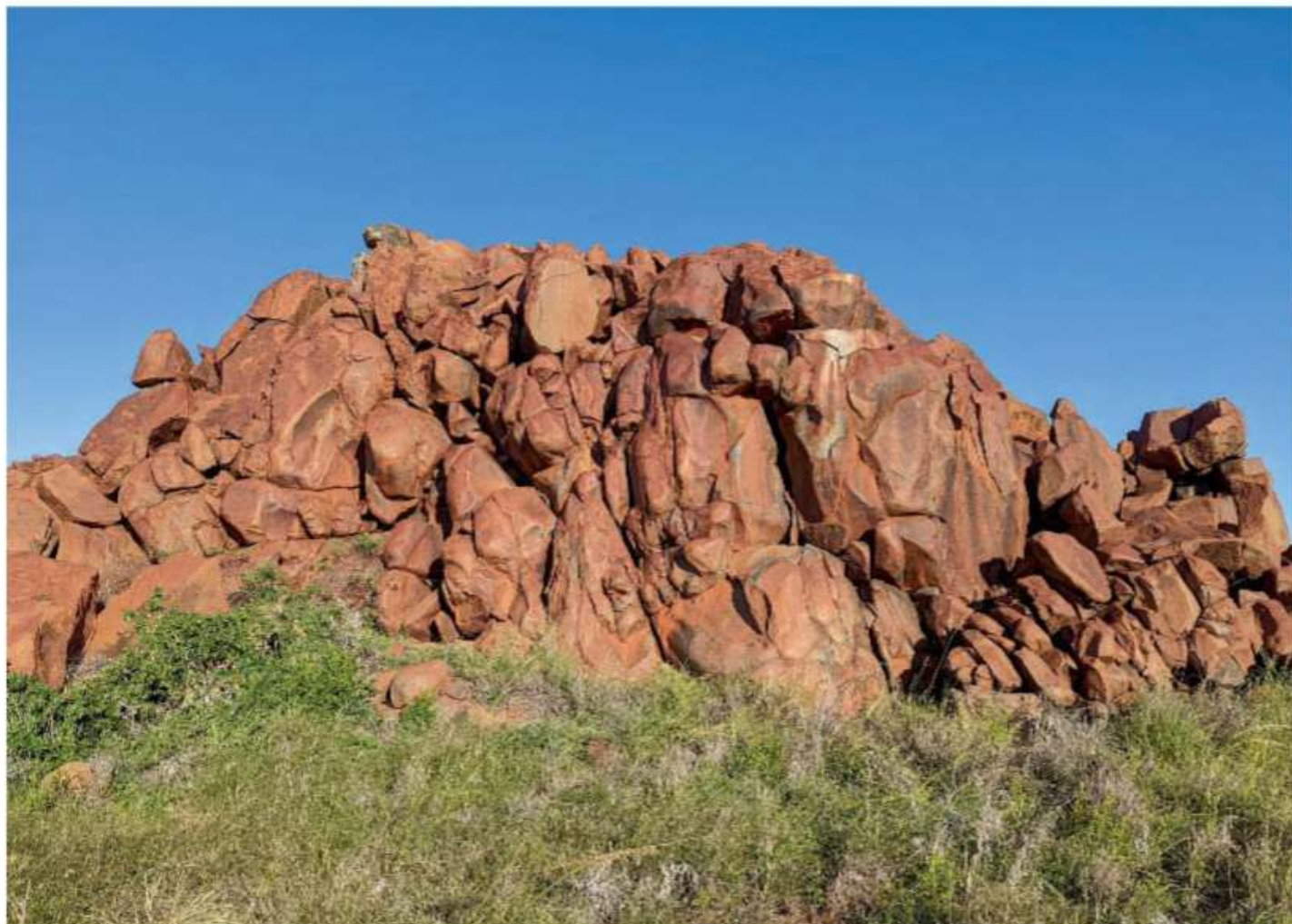
“Large jumbles of rocks change from orange to red to pink to purple as the sun moves across the sky”

making it the most continuous sequence of rock art in the world. It is also among the oldest, coming close to Spain's record-breaking 66,700-year-old cave paintings.

Murujuga, which means “hip bone sticking out” in the local Ngarluma-Yaburara Aboriginal language, refers to a peninsula jutting out of the remote Pilbara region. It also includes surrounding islands that were connected to the mainland until about 7000 years ago, when they were cut off by a 130-metre sea level rise that began after the last glacial maximum.

I have come here to join an archaeological and geological expedition by researchers from the University of Western Australia and the University of Wollongong in New South Wales. They are seeking to precisely date the rock art and understand more about how its surrounding environment has changed.

Current estimates of the art's age, at about 50,000 years old, are based on the dating of stone tools and other human artefacts found in a nearby cave. Only now is the art itself being directly dated.



ALL PHOTOS: ALICE KLEIN

To get here, we took a helicopter from Karratha, a nearby mining town. It was blowing a gale when we arrived at the airport and I was nervous about my first-ever helicopter ride. However, our pilot said I shouldn't panic unless I see him pull his visor down to mask the fear in his eyes, which was reassuring.

Dating rocks

Thankfully, we landed in one piece on a northern island of Murujuga called Middle Gidley. The landscape is spectacular in a sparse, rugged way. There are no trees, just spiky spinifex grass interspersed with large jumbles of rocks that change from orange to red to pink to purple as the sun moves across the sky. I can see how this scenery has inspired a torrent of human creativity.

There is art all over the rocks – images of people dancing, boomerangs, boats, wallabies, emus and extinct species like fat-tailed kangaroos and thylacines, or Tasmanian tigers. The newer art captures whales, fish, crabs and turtles that arrived when rising sea levels turned the once-inland region into a coastal area. The unusual hardness and low weathering rates of the rocks have exquisitely preserved the drawings, made by scratching or carving the surface with sharpened stones.

Luke Gliganic at the University of Wollongong is trying to date the art using a technique called optically stimulated luminescence surface exposure dating. The idea is to measure the rate at which freshly exposed surfaces of the rocks at Murujuga – like those formed during carving – lose electrons, which occurs upon

light exposure. The age of the ancient carvings can then be extrapolated by measuring their electron loss to date.

We hop back on the helicopter to fly to nearby Rosemary Island, where Gliganic has been given permission from traditional owners to make an experimental carving on one of the rocks. He

“There's nowhere else on Earth you can peer so clearly into a 50,000-year story of humanity”

uses a drill, hammer and chisel to cut small cores out of the rock surface. To limit light exposure, he then quickly wraps them in foil to take to his lab. Gliganic will collect more of these samples during future trips to establish the rate of electron loss across a given time period.

**Left: Rocks on Middle
Gidley island in Murujuga
that typify the landscape.
Right: Some of the more
recent engravings depict
sea creatures like turtles**

50,000

The estimated age, in years,
of the rock art at Murujuga,
Western Australia

2 million

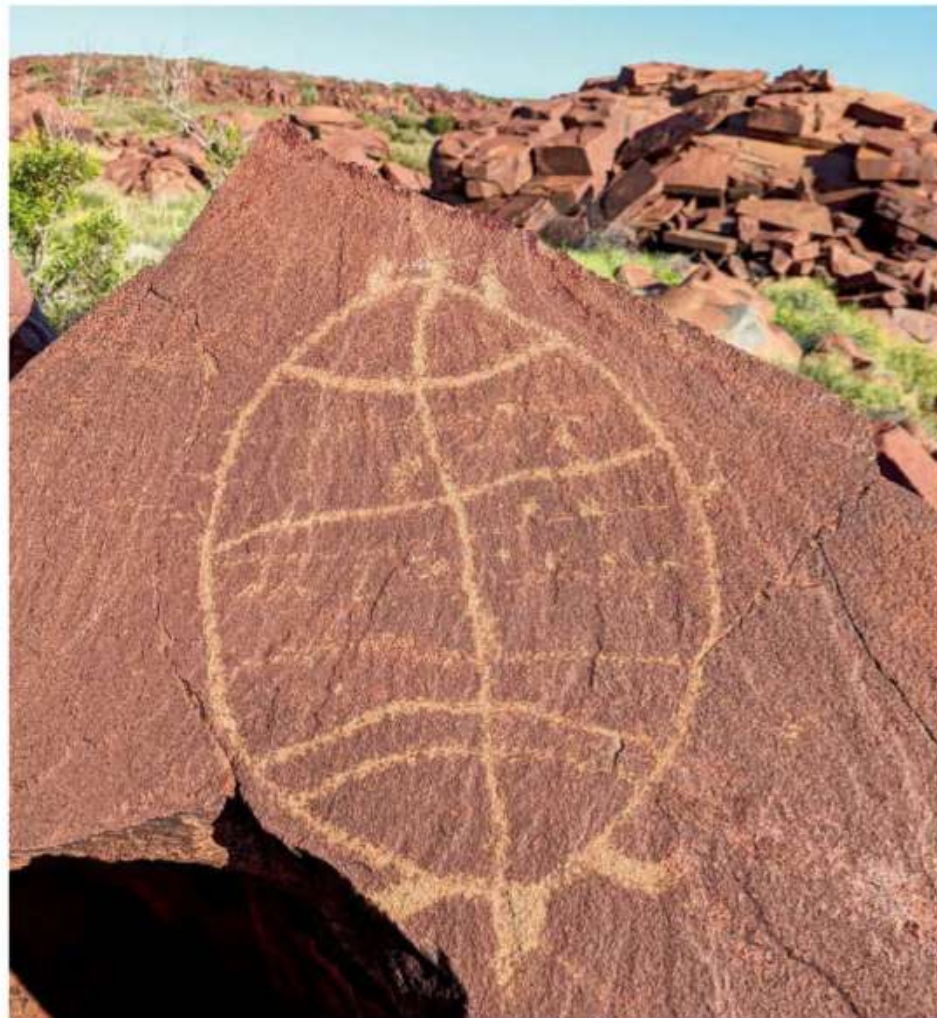
The approximate number of rock
engravings in Murujuga

66,700

The age, in years, of Spain's
record-breaking cave paintings

Back on Middle Gidley, Matthias Leopold, Caroline Mather, Mick O'Leary and Diego da Silva Turollo, all at the University of Western Australia, are working on a way to try to reconstruct historical climate records for Murujuga. Normally, these are reconstructed by studying tree rings, ice cores or stalagmites and stalactites in caves, but the sparse landscape of Murujuga offers none of these things, so the researchers have had to get creative.

They previously found a shallow basin in Middle Gidley that contains layers of sediment that have built up over time. These layers may hold clues to past environmental conditions and, with any luck, could contain ancient stone tools that can be dated based on their depth. Traces of pollen may also indicate changes in vegetation.



The researchers fire up a large drill, which they use to drive metal tubes into the ground and extract 10-metre-long cores. It is back-breaking work, especially with the blazing sun overhead and no trees to provide shelter. Once the cores are ready, they are carried back to the mainland in a large net swinging below a helicopter.



**Below left: Rock samples
are collected to age the
art via its electron loss.
Below: A carving of an
extinct fat-tailed kangaroo**



There, they will be transported by truck 1500 kilometres to the University of Western Australia for analysis.

Art uncertainty

Exhausted and streaked with red dirt, we finally set up camp as the sun starts to dip below the rocks. Lying in my tent, I think about the first people who arrived here, who had to pull off one of humankind's first-ever open water crossings to get to Australia, from somewhere in south-east Asia. After travelling down the coast, they chose this spot to begin capturing their stories. Their enduring art has allowed them to continuously pass on their ancient wisdom and traditions, with Murujuga people today still performing some of the dances and rituals illustrated on the rocks.

Unfortunately, there is uncertainty about how long the art will last. Some scientists and traditional owners believe that emissions from a nearby liquefied natural gas processing plant may be damaging the rock art, although others have found no evidence of this. The government of Western Australia has partnered with the Murujuga Aboriginal Corporation to research whether the rock art is being damaged, but the results aren't expected for years.

Certainly, everything should be done to protect this special place. There is nowhere else on Earth where you can peer so clearly into a 50,000-year-long story of humanity, spanning massive climate shifts, dramatic sea level rises and changes in flora and fauna. As Adams says: "It's not only significant to Aboriginal culture, it's [significant to] the whole world." ■

Animal cognition

UK lab for clever birds saved from closure by public donations

Alison George

A CENTRE for research on bird intelligence at the University of Cambridge has been saved from closure by a campaign, kick-started by a *New Scientist* article, that raised £500,000 from public donations in a matter of weeks. Together with support from the university, the campaign has secured the facility's immediate future.

In May, we reported on the race to rehome the 25 jays and seven rooks in Nicola Clayton's Comparative Cognition Lab, which was facing closure in July due to Brexit and pandemic-related funding difficulties.

The report prompted Jonathan Birch at the London School of Economics to write an open letter calling on the university to reconsider the closure of the lab and to give the facility long-term support. "The international significance of the lab is hard to overstate and its closure would be a terrible loss to the sciences of mind and brain," says Birch.

The letter quickly attracted signatures from 358 leading academics, including Eva

Jablonka, Steven Pinker and Noam Chomsky. Donations from the public to support the lab also rolled in, totalling £500,000, which will keep the facility running for the next five years.

"I've been overwhelmed in the most positive way by the support from the University of Cambridge, fellow academics and the general public from all walks of life," says

Two rooks at the Comparative Cognition Lab in Cambridge, UK



FRANCESCA M. CORNER/UNIVERSITY OF CAMBRIDGE

Clayton. "Every penny, I'm so grateful for. It's been an emotional roller-coaster, with a heart-warming, positive ending."

The facility, founded 22 years ago by Clayton, has been key to understanding the cognition of corvids – members of the crow family. Its research has shown how these birds have abilities once thought to be the domain of only humans and great apes, such as understanding the minds of others and mental time travel, which involves reflecting on the

past and planning for the future.

For Clayton, the closure of the lab was personal, not least because she and her team had hand-reared the birds from chicks and invested years to ensure they were willing and happy participants in the research. "If you want to have a window into how these birds think, you need to have their trust and respect," she says. This close, long-term relationship between the birds and the researchers meant that the facility couldn't easily be set up elsewhere.

"This really is fantastic news," says Jablonka, who is at Tel Aviv University in Israel. "It is extremely important that the research in this unique centre continues."

Clayton already has ambitious ideas for future research with the corvids. However, rooks can live for perhaps 80 years, so she hopes that more funding will be forthcoming, to keep the facility going beyond the next five years. "Working with these long-lived, clever birds is a long-term project," she says. "You can't just stop and start." ■

Atmospheric physics

Firing a laser into the sky can redirect lightning's path

A LASER that redirects lightning could be used to protect critical buildings during storms.

When an electric charge builds up in clouds, lightning can propagate downwards, from the clouds to the ground, or upwards, from tall objects towards the clouds. In either case, conductors such as metal rods are generally used to redirect the electric current away from vulnerable targets and into the ground.

Efforts to control lightning have involved firing rockets with wires attached into clouds to force them to discharge their lightning. However, in the 1990s, people started to experiment with using lasers to redirect the current instead. While the technique proved successful with artificial lightning, it had never been demonstrated in a real storm.

Now, Jean-Pierre Wolf at the University of Geneva, Switzerland, and his colleagues have fired a series of very short, high-powered laser pulses from a 124-metre-high tower equipped with a

standard metal lightning rod, on Switzerland's Säntis mountain.

The terawatt laser was fired upwards during thunderstorms over a three-month period, for a total of 6.3 hours of operation time. During that period, the tower was hit by at least 16 lightning flashes, which propagated up to the clouds from the tower. Wolf and his team recorded the paths of four streaks of lightning heading up from the

"The research will help us understand the processes by which lightning finds its way to ground"

metal rod, along the path of the pulsing laser, using high-speed cameras, interferometry and X-ray detectors (arXiv, doi.org/h5wc).

"Scientifically, I think it's really interesting," says Chris Scott at the University of Reading, UK. "It will help us understand the processes by which lightning finds its way to ground."

When a storm is brewing, it may be possible to use lasers to trigger lightning at a safe distance from anything that needs protecting, by having the current follow the path of the laser. ■

Alex Wilkins

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Concerns over catching covid-19 in hospital The coronavirus may become a potential hazard of going to hospital unless we introduce new measures to stop the spread, says **Clare Wilson**

DOCTORS are becoming increasingly concerned about the rising rate of covid-19 infections acquired in hospitals. They fear that the coronavirus is becoming a potential hazard of hospital stays for older or vulnerable people, in a similar way to “superbugs” such as methicillin-resistant *Staphylococcus aureus* (MRSA).

People who go to hospital for non-covid-19 treatment are at higher risk from the virus compared with the general public, says Tom Lawton, an intensive care doctor in Bradford, UK, as covid-19 can be more severe if you have other medical conditions, physical injuries or need surgery.

Hospital-acquired covid-19 has been happening since the start of the pandemic, but the problem is likely to be worsened by the higher infectiousness of the omicron variants that have been predominating since the start of the year, says Michael Klompas at Harvard Medical School.

The proportion of people in hospital in England infected with covid-19 who caught it while in hospital has now reached its highest recorded level, at 24 per cent as of 10 July, according to figures calculated by Lawton using data from NHS England. NHS England didn’t respond to a request for comment before publication.

While comparable figures aren’t made available in other countries, including the other UK nations, some UK doctors suspect rates of hospital-acquired covid-19 are particularly high because most UK hospitals have large wards with many beds. By contrast, in the US, for instance, most hospital patients stay in single or double rooms and hospitals have higher ventilation standards.

Regularly testing hospital patients for covid-19 can also

HANNAH MCKAY/BLOOMBERG VIA GETTY IMAGES



Staff wearing masks at the Royal Blackburn Teaching Hospital, UK

be a way of reducing spread, as people found to be positive can be isolated. But in Sweden, for instance, hospitals now rarely test asymptomatic people.

Healthcare workers in Sweden tend to be less concerned about preventing the spread of covid-19, perhaps stemming from the country’s more hands-off attitude to covid-19 restrictions, says Katrin Rabiei, who was formerly a doctor at NU Hospital Group in Sweden. “It is really lax,” she says. “The norm is no covid precautions.”

Most countries don’t take hospital-acquired covid-19 cases as seriously as they do the spread of other hospital-based superbugs, like MRSA – but they should, says Matt Butler at Cambridge University Hospitals. “What we don’t do is say, ‘Where did they get it from?’ For MRSA, *Clostridium difficile*, norovirus, we sit round a table and we do the genomics to find out where it came from.”

“We spend a lot of money on shampoos and creams to treat skin colonisation with MRSA, but we do nothing to stop hospital-

acquired covid,” says Butler. “But covid is much worse than skin colonisation with MRSA.”

Several studies have found that people who have other illnesses or need surgery are more likely to die if they also have covid-19. For instance, in people needing surgery to repair a broken hip, 30 per cent died within one month of surgery if they had covid-19 within either a week before the operation or a month afterwards, a large international study found. Although this study didn’t directly compare people who had covid-19

“We spend a lot of money to treat MRSA, but we do nothing to stop hospital-acquired covid-19”

with those who didn’t have it, this death rate is much higher than usual after hip repair, which is about 6 per cent in the UK.

“No one’s health is going to be improved by getting covid,” says Butler. “We are seeing many people getting clots, or they get delirious, start wandering and can fall.”

These studies were done before the current omicron variant became dominant and before so many people had been vaccinated and boosted, so it is possible that

the current effect of covid-19 on death rates is less, says Chetan Khatri at the University of Warwick, UK. “But it does worsen the death rate for all kinds of surgery.”

What can be done? There are no large, randomised trials where hospitals try different ways to reduce the spread of the coronavirus, although there are hints from other kinds of studies.

For instance, in December 2020, Addenbrooke’s Hospital in Cambridge, UK, started giving higher-quality respirators to all staff working on covid-19 wards, when previously only basic face masks had been offered. Before the change, staff on covid-19 wards had a nearly 50-fold higher risk of becoming infected than those on non-covid-19 wards. With the respirators, the risk to staff was about the same regardless of ward.

Another possibility is to have machines called HEPA filters placed by beds. These remove small particles from the air, including tiny exhaled water droplets containing viruses.

A study carried out at Addenbrooke’s showed that using these machines removes coronaviruses from the air – although research to see if they reduce infection rates is still ongoing. The disadvantage of the machines is that they can be noisy and cause drafts if not directed away from patients, says Butler.

Covid-19 prevention practices may not change until more results from research are available showing that steps such as HEPA filters, respirators and increased testing improve patients’ outcomes. But there is still more that can be done. At the moment, many hospitals aren’t testing people who are asymptomatic, says Klompas. “If you don’t measure it, you won’t know.” ■

Mental health

No link between depression and serotonin, finds major analysis

Sarah Wild

THERE may be no link between serotonin levels and depression, according to an analysis of 17 studies. This raises questions about antidepressants that focus on this brain-signalling molecule, say the authors of the analysis. Not everyone is convinced by the findings, though.

The serotonin hypothesis, which dates from the 1960s, says that a chemical imbalance in the brain, including low levels of serotonin, also known as 5-hydroxytryptamine or 5-HT, leads to depression. We now think many biological, psychological and environmental factors play a role, but the most popular antidepressants – selective serotonin reuptake inhibitors (SSRIs) – increase the availability of serotonin in the brain.

Now, Joanna Moncrieff at University College London and her colleagues have done an “umbrella analysis” of

17 systematic reviews and studies, which together included hundreds of thousands of people with and without depression.

It is difficult to directly measure real-time serotonin levels in the brain, so the 17 studies looked at proxies, such as the molecules in cerebral fluid that serotonin

“Antidepressants vary in effectiveness for different people, and the reasons for this are complex”

breaks down into; the levels of serotonin receptors and how active they are; or whether there are more genes for mechanisms that remove serotonin in people with depression.

Moncrieff’s team found no evidence that low serotonin levels cause depression (*Molecular Psychiatry*, doi.org/gqh6nd).

“The implication of our paper is that we do not know what

[SSRI] antidepressants are doing,” says Moncrieff. One possibility is that they are working through a placebo effect, she says.

However, Johan Lundberg at the Karolinska Institute in Sweden says the analysis didn’t distinguish between people who had ongoing depression and those who have episodes of depression, whose state when they were assessed could affect their serotonin systems. “It is key to separately analyse data from studies that examine the same patients when ill and when in remission, to have optimal conditions to examine the hypothesis,” he says.

Moncrieff says the review was dependent on the studies that had already been done, none of which highlighted any difference between people who were experiencing symptoms of depression or had a history of it.

“It must be recognised that 5-HT is likely only one contributor to

depression,” says Paul Albert at the University of Ottawa in Canada. “Given the large placebo effect in treatment of depression, it is likely that the contribution of other systems, including dopamine that is implicated in placebo effect, may be greater than that of 5-HT.”

Antidepressants are an effective treatment for depression that are recommended by the National Institute for Health and Care Excellence in England, a spokesperson for the Royal College of Psychiatrists told the Science Media Centre in the UK.

“Antidepressants will vary in effectiveness for different people, and the reasons for this are complex,” the spokesperson said. “We would not recommend for anyone to stop taking their antidepressants based on this review and encourage anyone with concerns about their medication to contact their [family doctor].” ■

Palaeontology

Inner ears reveal when animals evolved warm blood

THE first warm-blooded animals appeared abruptly 233 million years ago, according to clues hidden deep inside their ears.

Before now, scientists estimated that warm-bloodedness, or endothermy, gradually evolved over a period of about 120 million years based on vague clues from animals’ skeletons and their environments. But Ricardo Araújo at the University of Lisbon in Portugal and his colleagues suspected that the semicircular canals in the inner ear might provide a more precise record.

These fluid-filled canals help

animals maintain balance and keep their sense of orientation. But because temperature affects the way fluids behave, warm-blooded animals would, in theory, have had to evolve a different inner ear shape from their cold-blooded ancestors in order to keep their orientation system working properly.

Araújo and his colleagues used an X-ray scanning technique called microtomography to examine the inner ears of hundreds of modern animals, including mammals, reptiles, birds, amphibians and fish, and 64 extinct species of mammalian predecessors.

They found that in mammals, which are warm-blooded, the inner ear canals were more circular and smaller and thinner relative to their body size, compared with



Illustration of an early warm-blooded ancestor of mammals

those in cold-blooded reptiles, amphibians and fish.

That trend was so reliable that the researchers soon realised that they could identify whether animals were warm-blooded or cold-blooded “with a lot of

confidence” just by looking at their inner ears, says Araújo.

Armed with that knowledge, the researchers looked at the inner ear canals in their ancient specimens spanning several hundreds of millions of years. They determined that mammal ancestors first became warm-blooded over a roughly 1-million-year period during the late Triassic, 233 million years ago (*Nature*, doi.org/h5vq). This corresponds with the first known appearance of mammaliamorphs, ancestors of mammals that may have had the first hairs and whiskers. ■

Christa Lesté-Lasserre

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Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **Plantlife**



DOMINIC MURPHY

Roadside sanctuary

While there has been some real progress in the management of grassy road verges many are still cut at least four times a year despite Plantlife-led guidelines recommending a two-cut management programme that allows flowers to complete their full lifecycle rather than being cut down in their prime before they are able to set seed. Where safety allows, the less and later two-cut approach endorsed by highways agencies, industry and wildlife organisations would replenish the seed bank, restore floral diversity, save councils money and provide pollinator habitat estimated to equal the size of Dorset. Clearing cuttings to a hedgerow base or collecting them wherever possible is key.

Fresh approaches to road verge management are essential considering there has been a 20% drop in floral diversity on road verges since 1990, partly due to poor or inappropriate management. Red clover and lady's bedstraw, two of the six verge wild

flowers that support the highest number of invertebrates - are amongst the plants experiencing the most rapid decline with adverse knock-on effects for wildlife. The potential use of verge cuttings for bio-energy is being investigated to reduce costs and carbon, while AI is showing promise in identifying the best road verges for wildlife.

Given a staggering 97% of wildflower meadows have been eradicated in less than a century, grassland road verges are crucial wildlife habitats. They provide safe haven for over 700 species of wild flowers, nearly 45% of our total flora, including 29 of 52 species of wild orchid including rarities such as Lizard orchid. Not only that, but our road verges have

the potential to act as a network of ecological corridors - supplying and supporting our countryside, towns and cities with wildlife by acting as a living vascular system for nature.

The road verges campaign is an integral part of Plantlife's concerted conservation mission to save, restore and protect all grassland habitats, including wildflower meadows. Given permanent grasslands hold up to a third of the Earth's terrestrial carbon they are crucial in the fight to combat climate change.

Want to help?

Encourage your council to cut road verges less and later for nature. Find out more at roadverges.plantlife.org.uk

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Covid-19

Coronavirus may enter brain via nanotube tunnels

Alice Klein

WE MAY finally know how covid-19 reaches the brain: the coronavirus could stimulate the growth of tiny tubes between nose and brain cells that it then moves through.

Covid-19 has been linked with a range of neurological symptoms. Autopsy studies have also detected the virus in people's brains. But how it gets there was a mystery. Previous studies suggest the ACE2 receptor the virus uses to enter cells is barely detectable in the brain.

To learn more, Chiara Zurzolo at the Pasteur Institute in France and her colleagues did experiments in a dish with the coronavirus and two cell types: one to model brain cells and one to model cells that line body surfaces, including the nose.

On their own, the model brain cells couldn't be infected because they lacked the ACE2 receptor. But when incubated with the model nose cells, which had the receptor, they became infected. Upon entering the model nose cells, the virus stimulated them to grow tunnelling nanotubes, forming links with the model brain cells (*Science Advances*, doi.org/gqjczs).

The virus then used these tunnels to shuttle between the cell types. "I think it's a very interesting study because it provides a nice, neat mechanism by which the virus can be transferred from one cell to another while bypassing the need for ACE2 receptors," says Frederic Meunier at the University of Queensland in Australia.

But because the experiments were limited to cells in a dish, further studies are needed to confirm the mechanism occurs inside the brain, says Meunier.

If tunnelling nanotubes are confirmed to transport the virus to the brain, we may be able to make drugs to block them, says Zurzolo, whose group is setting up "organ-on-a-chip" experiments to mimic the interactions between the cells. ■

Analysis Climate change

UK government's headache over net-zero strategy

Following a legal battle, the country's next prime minister will have to sign off on a new climate plan, says **Adam Vaughan**

A DAY before the UK recorded its hottest temperature ever in a climate change-fuelled heatwave that reached 40°C, the UK government lost a legal battle over its blueprint for cutting the carbon dioxide emissions that drive such extreme weather.

High Court judge David Holgate ruled on 18 July that the government's net-zero strategy was unlawful, following a judicial review brought by three groups: ClientEarth, Friends of the Earth and the Good Law Project.

The flagship plan was ruled unlawful in two ways. The first is that the minister who signed off on the strategy, Greg Hands, was deemed to have not had enough information to know that its policies and proposals – such as backing a new nuclear power station – would enable carbon targets to be met.

The second is the strategy failed to offer sufficient detail on how much individual policies would cut emissions, which is crucial information to enable scrutiny. Both failings fell short of obligations under the 2008

8

Months until the UK government must publish a new climate plan

Climate Change Act, a landmark law that many countries have looked to emulate.

James Cameron, a barrister and entrepreneur who wasn't involved in the case, says the judgment is a big moment. "We are now entering a time where we need the law to represent our interests as a society in survival and human flourishing," he says. A UK government spokesperson says: "The net-zero strategy remains government policy and has not been quashed."

Nonetheless, the ruling will pose



TOLGA AKMEN/DANIEL LEAL/AFP VIA GETTY IMAGES



Liz Truss (left) and Rishi Sunak (right) are competing to be the next UK prime minister

a major task for the next prime minister, as well as for whoever is appointed energy secretary. This won't happen for a few weeks, as the Conservative party is due to choose either Rishi Sunak or Liz Truss as its new leader and UK prime minister on 5 September.

Holgate's judgment orders the government to publish a report by the end of March 2023 that meets the Climate Change Act's obligations. This means quantifying the emissions that individual policies will contribute to future carbon targets.

"It's basically telling the government: provide the information which the current net-zero strategy lacks on the impact of the policies you're talking about," says Tony Bosworth at Friends of the Earth.

Tim Lord at the Tony Blair Institute, a former senior civil servant, tweeted that the ruling was very significant in one sense: "It presents an incoming PM and energy secretary with a big challenge (or opportunity, if you prefer): they will have to put their name to a new net-zero strategy by March 2023. No hiding behind the current one."

The government is understood to hold a spreadsheet of the emissions savings of the individual policies, but has repeatedly refused to release it despite freedom of information requests by *New Scientist*. The Information Commissioner's Office is currently considering an appeal over the refusal, and MPs have urged the government to reconsider its stance.

Exactly what the government's new strategy will look like remains to be seen. It is most likely that it will be an updated version of an existing October 2021 document deemed inadequate in Holgate's ruling, or theoretically it could be an entirely new strategy. Either way, Bosworth says Holgate's ruling gave considerable weight to the views of independent advisory group the Climate Change Committee (CCC) on the strategy, strengthening its role.

The CCC last month found that only 39 per cent of the emissions cuts required to meet carbon targets for the mid 2030s are backed by credible policies. Most of the rest are endangered by a "policy gap" or "significant risks". The fallout of the recent court verdict is clear: the government will have to rapidly strengthen its plans for cutting emissions and be much more transparent in the process. ■

Coronavirus

Covid-19 may raise premature birth risk

HAVING covid-19 after 34 weeks of pregnancy has been linked to a seven-fold higher risk of giving birth prematurely.

Tal Patalon at Maccabi Healthcare Services in Tel Aviv, Israel, and her colleagues tracked the outcomes of 2753 women who had a positive covid-19 test at any stage of their pregnancy, compared with the same number of pregnant women who didn't.

They found that 9.1 per cent of those who had a positive covid-19 test after 34 weeks went on to give birth prematurely, defined as less than 37 weeks into the pregnancy. This is compared with 1.4 per cent of the women who didn't test positive while pregnant. The researchers didn't account for the women's covid-19 vaccination status (*PLoS One*, doi.org/gqh8g2).

Clare Wilson



SCIENCE PHOTO LIBRARY/LAMY

Life

Fish took 'backward' step in evolution

A SCALY, finned creature that lived in water 385 million years ago descended from four-legged land animals, in a clear example of a "backward" step in evolution.

Some fish grew legs and developed the ability to stand nearly 400 million years ago. But the smooth limb bones of the newly described *Qikiqtania wakei* fossil couldn't have supported the muscles needed for standing, meaning it had evolved back into a swimming, full-time water dweller, says Neil Shubin at the University of Chicago. Shubin and his colleagues unearthed the fossil in the Canadian Arctic Archipelago in 2004 (*Nature*, doi.org/h5vh).

"The ancestors of *Qikiqtania* were already taking those steps [out of water], but this was a creature that said, 'I'm not doing that, I like the water better!'" says Shubin. Christa Lesté-Lasserre

Solar system

Enceladus's oceans may be right saltiness for life

THE way ice covers the surface of Saturn's moon Enceladus suggests that the oceans trapped beneath it may be only a little less salty than Earth's oceans. The finding adds to the possibility that this moon might be able to sustain life.

Wanying Kang at the Massachusetts Institute of Technology and her team wanted to determine what the characteristics of Enceladus's ice shell indicate about the ocean beneath it.

The team devised a model detailing how ocean salinity, ocean currents and ice geometry affect each other on a planet or a moon, then tweaked it to best reproduce the properties of Enceladus's ice.

The researchers found that saltier

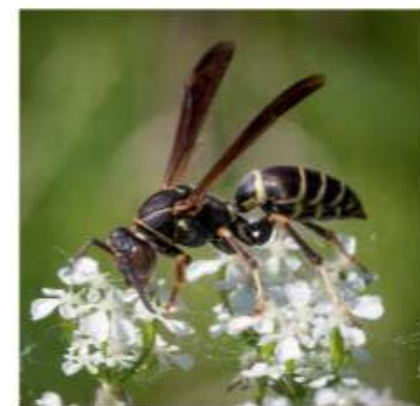
subsurface oceans correspond to thicker ice on a planet's poles than over its equator and vice versa for less salty water. On Enceladus, the ice over the poles is thinner than the ice over the equator. The specific variation in thickness suggests that the ocean's salinity could be as high as 30 grams of salt in a kilogram of water (*Science Advances*, doi.org/h5st). For comparison, Earth's oceans have a salinity of 35 grams of salt per kilogram of water.

The researchers also determined details of water circulation under the moon's ice. These currents are related to temperature differences in the water, so understanding them is also important for determining habitability, says Kang.

The team found that some heat emanates from the bottom of the moon's ocean, possibly indicating the existence of heat vents in the ocean floor. Kang says that some astrobiologists have suggested that, like on Earth, such hydrothermal vents could be where life is found.

Karmela Padavic-Callaghan

Really brief



MARCO PHOTOS/GETTY IMAGES

Wasps can handle abstract concepts

Paper wasps (*Polistes fuscatus*) can learn to distinguish between pairs of stimuli that are the same or different, demonstrating a grasp of abstract concepts. Such cognitive abilities have only been shown in a relatively small group of animals, including some birds, dolphins and honeybees (*Proceedings of the Royal Society B*, doi.org/gqh728).

Pufferfish toxin could block pain

A quicker way of making one of the world's most potent neurotoxins could open doors to advances in pain research. Tetrodotoxin, the poison found in pufferfish, blocks nerve signals very efficiently, so the hope is it can be developed into a pain-relief drug (*Science*, doi.org/h5vm).

Spinning rotor made from DNA

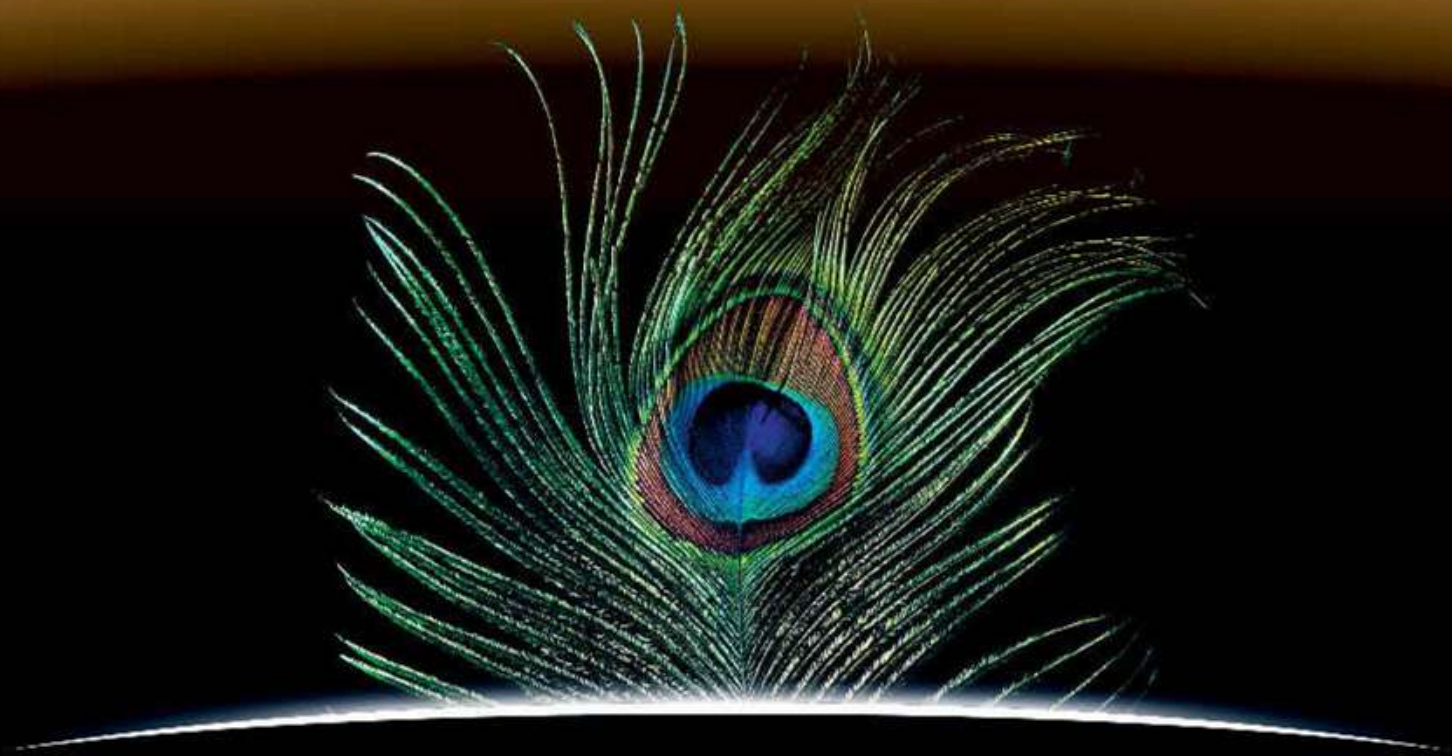
A nanoscale rotor has been made from DNA, with a blade about a thousand times thinner than a human hair. It could be used as a tiny valve for tasks like sorting molecules or act as a switch in a biological computer (*Nature*, doi.org/gqjcfq).

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Culture columnist

Sally Adee on solarpunk novel *The Moonday Letters* **p34**

Comment

The nature divide

Going birding made a huge difference to my family's mental health. Access to nature must be a right, not a privilege, says **Mya-Rose Craig**

IN MY memoir, *Birdgirl*, I write about my experiences as a child birding with my family and how those days saved us, giving us a reason to live and a way to cope with my mother's bipolar disorder, a mental illness with devastating lows and highs. These experiences reinforced in me why being in nature is essential for our mental well-being.

Growing up, I went birding with my white father, my British-Bangladeshi mother and my sister. I never saw people who looked like me. I was determined to change this, and by the time I was 14, I had run two nature camps; held a conference, Race Equality in Nature; and set up my charity, Black2Nature. I bombarded nature charities with ideas for how to connect with what I call visible minority ethnic (VME) communities – minority ethnic people who describe themselves as non-white. My mantra was, if I can engage young VME people with nature, so can you.

We live in a village south of Bristol, UK, where racism only touches a few families like ours. Most people rarely mention Black2Nature, except to tell my mother (always her) that white boys from south Bristol are more disadvantaged than VME teenagers and so focusing our work on them is divisive and racist. They point to a charity that takes disadvantaged teenagers to camps in the countryside. Although it does great work, when I look at its



SIMONE ROTELLA

photos, I don't see equality – I see a sea of white faces.

According to a 2016 Natural England study, 74 per cent of white British children visited green spaces weekly, compared with 56 per cent for Black, Asian and minority ethnic children. The 2019 Landscapes Review showed that the UK's national parks didn't attempt to engage the high number of people who are of a minority ethnicity and living in cities by, for example, ensuring cheap buses.

A 2017 report found that of environmental professionals, only 0.6 per cent are non-white, leaving

them without the knowledge to engage VME communities. Through Black2Nature, we reach out to VME parents and their teenagers to gain their trust. We work with community leaders and groups, dealing with fears such as their children being given pork, so they let them attend our camps.

It is indisputable that going into a green space improves the well-being of both adults and children, reducing their chances of experiencing symptoms of mental illness. A Mental Health Foundation report found that how we connect with nature is important for how well

we manage our mental health.

Statistics show Black men are 10 times more likely to have experienced psychosis compared with white men. Around 68 per cent of white British people had improved outcomes after treatment for anxiety or depression in 2018 to 2019, while only 61 per cent of Bangladeshi people in the UK did, something I could relate to with my mother. As Michael Marmot wrote in his 2020 review of inequity in healthcare, "avoidable health inequalities are unfair and putting them right is a matter of social justice".

Compared with white young people, Black and Asian young people are around twice as likely to be referred to mental health services via social care and youth justice systems than via primary care settings. It is clear that their mental health issues are only identified when society has already failed them. The disparity between VME and white teenagers is stark and so equal access to nature for all can make a real difference here.

It is essential for environmental organisations to work with charities such as Black2Nature, as well as with young VME people, to engage them with nature, improving their mental health and subsequent life chances. Access to nature should be a right, not a privilege. ■



MARK BREEDEN

Mya-Rose Craig is an environmentalist, diversity activist and author of *Birdgirl*

My botanical life

Is grass always greener? Artificial lawns have grown in popularity, but there are major drawbacks, says **Beronda L. Montgomery**, who is looking for an eco-friendly alternative



Beronda L. Montgomery is a writer, researcher and biochemist who studies how plants detect and respond to their local light environment. She is the author of *Lessons from Plants*. You can follow her on Twitter @BerondaM

Beronda's week

What I'm reading

Community as Rebellion: A syllabus for surviving academia as a woman of color by Lorgia García Peña

What I'm watching

As a distance bonding activity by invitation of my sister, I'm watching the delightful Johnson on Bounce TV

What I'm working on

Right now, unpacking boxes and exploring new outdoor areas

This column appears monthly. Up next week: Chanda Prescod-Weinstein

I RECENTLY stood surveying my new front lawn with a landscaper. The grass is a fine-bladed fescue variety that grows slowly, partly because it is a shade-tolerant species situated beneath the cover of my front yard's large oak trees. These grasses are efficient at photosynthesis and can produce enough sugars to grow in limited light.

It is important to know whether your lawn is populated by sun-loving or shade-tolerant plants because they have different nutrient requirements. All plants have relatively high nitrogen needs because chlorophyll, which is central to photosynthesis, contains nitrogen. Shade-tolerant varieties, however, generally have lower nitrogen requirements and higher potassium needs than sun-loving ones. Potassium appears to play an important role in helping these grasses increase their tolerance to stresses.

The lawn looked quite healthy to my eye, yet the landscaper informed me that the scattered weeds would be removed. I had to look closely to spot the weeds, which were green plants with broader leaves than the grass. I chuckled as I recited my often-shared mantra that weeds were just "good plants with a bad reputation". Within days of moving in, they began to disappear due to uprooting and herbicide application by the landscaper. The yard took on a commonly prized, uniform-green appearance as the plant diversity was reduced to just a single shade-tolerant grass species.

Across my typical Midwestern neighbourhood, there are a range of lawns, from those with a highly manicured, single-species grass variety to those with an increased diversity of mixed grasses and weeds. One common argument

against highly manicured grass lawns is that they negatively affect local plant and insect biodiversity. Researchers have suggested that lawn-owners should mow less frequently to increase both plant biodiversity and the number of pollinator visits, while also reducing pests without the need to use quite so many pesticides.

Discussions around ways to make lawns more sustainable have also seen a drive to accept lawns comprised of diverse plant species – rather than a single, aesthetically pleasing grass. The cultivation of lawn diversity

"Discussions around ways to make lawns more sustainable have seen a drive to accept diverse plant species"

is another way to decrease the need for pesticides and herbicides, because diverse communities of plants are more resilient.

The use of fully artificial turf has also increased around the globe, including in places where water is scarce. Artificial lawns have grown in popularity because they require less care and cut out the need for water and fertiliser, as well as the fuel associated with mowing. Given that grass maintenance requires roughly 3 trillion gallons of water per year in the continental US alone, according to the Environmental Protection Agency, concerns about water conservation are rightly considered when discussing the adoption of artificial lawns.

But these lawns come with notable drawbacks. Some are made with toxic or potentially damaging chemicals. After wear and tear, they must be replaced,

and many aren't readily recyclable. Although they are purported to save water, artificial lawns can compact the soil below them, which impedes rain uptake and increases water run-off; natural plants might rely on water to grow, but they can contribute to the water cycle through respiration. Artificial lawns also interfere with plant-insect interactions and can contribute to microplastic contamination.

Given the debates between the extremes of highly manicured, single-species lawns and similarly aesthetically pleasing artificial turf, I have thought frequently about compromises. I am not likely to adopt an artificial turf because of the ecological drawbacks, and because I love the smell of fresh-cut grass, but there are several alternatives.

These include cultivating lawns with herbaceous plants, which need less water and give a lovely green appearance, or with native plants that can act as ground cover and require little to no mowing. Bugleweed, for example, performs well in shady Midwestern yards such as mine. As a bonus, these plants can occasionally provide a colourful and delightful bloom!

Such plants are often adapted to outcompete weeds and thus provide greenery with little need for herbicides. Wild native grasses generally grow slowly, only require minimal or occasional mowing and serve as effective carbon sinks while supporting plant diversity. Increasing the plant-to-grass ratio in lawns is also a viable option.

So, while I write this looking out at an expansive single-species grass lawn with few weeds, I am thinking of the sustainable lawn I need to cultivate, which would bring equal aesthetic pleasure along with a greater sense of environmental responsibility. ■

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Anil Seth

Professor of Cognitive & Computational Neuroscience (Informatics), School of Engineering and Informatics, University of Sussex

Scan me to book



Editor's pick

On the search for a diet that extends lifespan

2 July, p 38

From Iain Climie,
Whitchurch, Hampshire, UK

I am not sure that a longevity diet is so clever, given that those most likely to benefit will have well-off Western lifestyles, so living longer will worsen their environmental impact. Should we take up smoking and dangerous sports on retirement to compensate?

A far more pressing requirement is to ensure the food security of lower-income countries and to find ways of rehoming climate refugees. With India at risk of becoming largely uninhabitable, who will house a billion people or more?

From Andy Taylor, Edinburgh, UK
While reading your article on the possibility that food choices may help us to live longer, it struck me that after decades of trying, we have been singularly unsuccessful in coming up with truly effective population-level dietary rules beyond the most basic, such as eat more fruits and vegetables.

Time and again, official advice fails to account for the significant variability between individuals. For example, there is mounting evidence that no two people metabolise food in the same way.

I suspect that the age-defying diet will prove the latest in a long line of false hopes. Wouldn't we have a better chance of addressing the very real health issues faced by millions of people in relation to the food we eat if we focused our limited research resources on developing a tailored approach to nutrition, rather than continuing the futile search for the wonder diet that will work for everyone?

From Greg Harris, Abu Dhabi,
United Arab Emirates

I was dismayed to see there were recommendations based on body mass index in a box in your article. While BMI is a useful measure at a

population level, it isn't suitable to be used at an individual level for medical or dietary advice. As the father of two athletically gifted children with low body fat and high muscle mass, I have had many messages from their school lamenting their state of "near-obesity". It is time to retire this nonsensical measure in all but the most circumscribed public health contexts.

From Rosalind King,
Penrith, New South Wales, Australia
Nutrition scientists seem to forget that eating is about pleasure as well as survival. Many people would trade longevity for enjoyment of life.

From Richard Robinson,
Brighton, UK

Dietary (and other) changes that extend life have a long history. There was agriculture 12,000 years ago, to feed us more efficiently. Artificial fertilisers arrived about a century ago, to feed more of us. More recently, modern medicine and the NHS arrived to keep us going for longer. Maybe with a true longevity diet, we will need another change: a new planet to accommodate us all?

Is the Higgs field just like the luminiferous ether?

2 July, p 42

From David Werdegar,
Naperville, Illinois, US
You describe the Higgs field acting as "a sort of invisible gloop that slows down particles like electrons and quarks". This description is suspiciously similar to the earlier idea of an "ether" as the carrier of electromagnetic waves, which Albert Michelson and Edward Morley disproved in their classic 1887 experiments. Recent optical

resonator experiments have confirmed their conclusions.

So how does the "gloop" of the Higgs field differ from the non-existent ether? Is it a case of different terminology, but the same concept?

We can get around the edible insect yuck factor

Letters, 9 July

From Michael Zehse, London, UK
Regarding Roger Browne's issues with eating insects. The yuck factor can be overcome by "processing" insects and including them in multi-ingredient dishes. Pending this development, insects are currently available for use in pet foods and livestock feed.

Airlines may need to warn us of solar storms

25 June, p 15

From Geoff Browne,
Sydney, Australia
With reference to your article on the link between solar storms and heart attacks, it seems to me that this could imply that people with cardiac problems shouldn't take long-haul flights during periods of increased solar storm activity. It seems that the convergence of disruption of circadian rhythms and increased solar storm activity could prove lethal.

Should airlines now publish warnings when solar storm activity is significantly elevated?

A tax could reduce fast fashion's eco impacts

4 June, p 38

From Steve Morris, Asseret, Israel
Your report presented a serious environmental problem – cheap fast fashion – while the cartoon by Twisteddoodles in the same issue

(p 56), looking at the cost of fossil fuels, suggests a possible solution: a new tax. If the tax on clothes purchases was increased, making them more expensive, demand would drop.

The extra revenue collected by governments could offset the reduction in fuel tax income as electric cars become more popular. Surely this would be preferable to the mileage tax on electric vehicles being discussed in a number of countries, since switching to them is a change that we need to encourage.

Battles with brain fog don't end for some

11 June, p 38

From Stephanie Woodcock,
Carnon Downs, Cornwall, UK
The term "brain fog" doesn't sound as frightening as the lived experience can be for those unlucky enough to have this symptom in a severe form. People differ and fortunately for Courtney Shukis, her "fog" resolved. Many aren't so lucky.

Brain fog was among my experiences with CFS/ME, which is very like long covid. In the ensuing decades, I have been fine, so I agree that in CFS, this symptom can be reversed. But as Julie Dumas says in the article, you do need to treat everything that can be treated.

Reasons to discount the idea of a block universe

18 June, p 38

From Nick Canning, Coleraine,
County Londonderry, UK
The assertion that we live in a block universe where time doesn't exist runs counter to two phenomena: the weather and radioactive decay. Deterministic chaos, as seen in meteorological phenomena, combined with quantum uncertainty, as exhibited in radioactive decay, mean that the fatalism (absolute determinism) implied by the block universe can't be a good description of our universe. ■



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Hunting universal truths

Some of cosmology's hardest questions relate to the universe's origins and the hunt for dark matter. **Michael Brooks** explores two new books taking them on



Books

Before the Big Bang
Laura Mersini-Houghton
Penguin Books

The Elephant in the Universe
Govert Schilling
Harvard University Press

HUMANS have always wanted to understand the universe: where it came from, how it works and how it will end. It is, perhaps, the thing that sets our species apart. The good news is that after hundreds of thousands of years of human evolution, we are finally getting believable answers – believable, that is, in the sense of passing certain experimental tests.

In a more everyday sense, however, the answers are unbelievable: the findings seem to show that our universe is just one among a myriad, all of which arise from quantum fluctuations. What's more, it is filled with stuff that is utterly resistant to every attempt to probe its character.

These strange findings are laid out in two new books that, while very different in scope and tone, are equally fascinating. In *Before the Big Bang: The origin of our universe from the multiverse*, cosmologist Laura Mersini-Houghton tells the story of her own investigations with delightful intimacy. We see her childhood struggles in communist Albania, where her father was banished to labour camps for ideological crimes and her mother was encouraged to divorce him in order to stay in the family's home.

As an undergraduate, Mersini-Houghton attended rallies against communism and saw her friends head to the West as soon as borders began to open. She stayed, developing a thick skin and a taste



NASA/ESA/STSCI

for radical thought. It has served her well.

It can be too easy for physicists to dismiss the question of where our universe came from as a lost cause, writes Mersini-Houghton. She is having none of it: "We have every right to wonder what existed in the cosmos fifteen billion years ago... and investigate."

That is exactly what she has done. Assembling clues from inflationary cosmology, string theory and quantum mechanics, Mersini-Houghton had an incendiary thought in a North Carolina coffee shop, writing "QM on the landscape" on a slip of paper as a reminder – "not that there was any danger I might forget", she tells us. She gives a lucid and fascinating explanation of where that thought was to lead.

By the end of her story, she has shown us the evidence that

Is our universe the result of a quantum fluctuation?

"The tale of dark matter is ultimately a tale of tenacity – and it is sometimes hard to see how it will ever end"

confirmed her predictions. Her conclusion? Our universe "arose from a bizarre quantum probability game and... is but a humble member in an intricate, vast and breathtakingly beautiful cosmic family".

A subtle but important aspect of Mersini-Houghton's book is her honesty about being a woman in physics. She tells us that she was afraid to open the door to receive a late-night bunch of flowers that her husband had sent, too worried the dark figure on her doorstep was the male colleague who had been harassing and threatening her daily. Such experiences are "routine" for women who have chosen a career in the sciences, she writes.

We catch glimpses of this in *The Elephant in the Universe: Our hundred-year search for dark matter*, a thorough and sometimes troubling account of the hunt for dark matter by veteran astronomy writer Govert Schilling. He mentions intimidating older male scientists, and cites Cecilia Payne-Gaposchkin, Vera Rubin and Elena Aprile among the astronomers who have had to jump extra hurdles because of their gender.

This is a necessary part of Schilling's story because the sexual politics of working in science have probably never been more in the spotlight than they are now. However, it doesn't dominate: he deftly steers us through this landscape while masterfully explaining why and how the science is so urgent.

Known as dark matter because it doesn't reflect or even absorb light, this exasperating stuff makes up more than 80 per cent of the matter in the universe. If, that is, it really exists. We think it does because stars and galaxies form and move in a way that suggests gravity nearby is stronger than can be accounted for by the mass of

Human stories

A Spanish bestseller about evolution celebrates curiosity itself, finds **Rebecca Wragg Sykes**



Book

Life As Told By a Sapiens to a Neanderthal

Juan José Millás and Juan Luis Arsuaga (translated by Thomas Bunstead and Daniel Hahn)
Scribe

IN THE Spanish city of Burgos, a towering 13th-century Gothic cathedral stands opposite the Museum of Human Evolution. Built 800 years apart, these buildings are both dedicated to finding meaning and exploring human origins, but the bones in the museum are 1000 times older than the cathedral, and its “high priest” is Juan Luis Arsuaga, a palaeoanthropologist.

Arsuaga’s work at the Atapuerca archaeological site, near Burgos, has helped shed light on Europe’s first humans. His ability to nimbly move from fossils and artefacts to scientific theories and philosophical ideas will now gain a wider audience with the UK publication of the Spanish bestseller *Life As Told By a Sapiens to a Neanderthal*.

Excavations at Atapuerca, near Burgos, Spain, shed new light on the first humans in Europe



AGEFOTOSTOCK/ALAMY

To produce this short yet dazzling book, Arsuaga joined forces with writer, novelist and columnist Juan José Millás. It is a wonderful distillation of their journey through human origins and evolution, which spans millions of years and an enormous geographic area.

The book is a testament to the time Millás spent visiting sites and talking with Arsuaga, which has fuelled his addiction to prehistory. “I read tirelessly because the Palaeolithic was one drug and the Neolithic was two drugs and the Neanderthals were three drugs,” writes Millás.

The charming result of this collaboration combines Millás’s surreal, ironic humour and beautiful reflections with Arsuaga’s expertise, expressed with sharp and surprising observations and an ability to bring prehistory up to date. The book tours a variety of ideas, from bipedalism, ageing and Ramón y Cajal’s theory of neurons, to chickpeas and penis bones – but it does so lightly and is always entertaining.

This is a book one can devour in a single sitting or gently nibble, and it will satisfy either way. My only criticism is that the narrative has a somewhat male perspective, but even this small niggle fits with the authors’ affectionate acknowledgement of humanity’s many blemishes.

Life As Told By a Sapiens to a Neanderthal is, ultimately, about curiosity and enquiry itself: a love letter to good conversation and great food, to ambling through time, place and thought, and an exaltation of the fact humans can wonder at all. ■

Rebecca Wragg Sykes is an archaeologist and writer based in Wales

the stuff we can see. But it could just be that we don’t fully understand how gravity works.

In 1922, astronomer Jacobus Cornelius Kapteyn first suggested the existence of dark matter. Schilling is exhaustive but never boring as he traces the evolution of the idea, and the theoretical leaps and experiments that have punctuated this century-long journey. He conveys the hopes and fears of dozens of scientists in these pages: optimism and frustration are ever-present.

The tale of dark matter is ultimately a tale of tenacity – and it is sometimes hard to see how it will ever end. One researcher, Suzan Başeğmez du Pree, tells Schilling that she hopes the issue will be solved within a decade, and if not “we may need to start thinking of something new. Or design new experiments.”

It seems that we will just carry on looking and speculating forever. The situation is, Schilling says, “crazy and maddening”. As he warns early in the book, don’t come here for answers: “Despite the efforts of many hundreds of persistent scientists, petabytes of data, and thousands of elaborate publications, we still don’t know the identity of more than 80 per cent of the material universe.”

That said, there is a lot we do know, and Schilling is an expert guide not only to dark matter and the equally baffling dark energy, which gets a good outing here, but to particle physics and cosmology. You won’t learn what dark matter is, but you will come away with a very good understanding of how the universe works. Well, our universe, anyway. ■

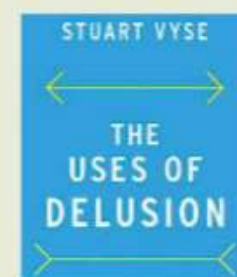
Michael Brooks’s latest book is *The Art of More: How mathematics created civilisation*. He is based in Sussex, UK. See *Inventory of the Universe*, page 36

Don’t miss



Visit

Zero to Birth reveals how the brain is built, as neurobiologist William Harris explores the development of the human brain in utero and a bit beyond. Catch it live at the Royal Institution, London, at 7pm BST on 8 August.



Read

The Uses of Delusion

are manifold, says psychologist Stuart Vyse. In this new book, he connects research into illogical thinking with its evolutionary origins and explains the possible benefits of irrational behaviour. On sale from 1 August.



Watch

The Sandman stars Tom Sturridge as the titular lord of dreams, imprisoned by humans (not for long, one would suspect) in this long-awaited adaptation of Neil Gaiman’s comic books. Streaming on Netflix from 5 August.

The sci-fi column

Hope is an action verb In Emmi Itäranta's *The Moonday Letters*, humans have adapted to the environments of their off-world habitats. While a cataclysm looms, at the heart of this genre-crashing thrill ride is an unexpected duty, says **Sally Adee**



Sally Adee is a technology and science writer based in London. Follow her on Twitter @sally_adee



GORODENKOFF/GETTY IMAGES

Living off-world is the norm in Emmi Itäranta's new sci-fi novel

One exception is Lumi Salo, whose journals make up the corpus of the book. She has been granted an exemption due to her calling as a healer, a shamanistic profession in huge demand since the exodus from ruined Earth.

This all sounds depressing, but the book is a thrill ride. Lumi's first journal entries are written as she leaves Europa to meet her spouse on Mars. A missed connection kick-starts a wacky caper in the style of *Where in the World is Carmen Sandiego?* This deepens into a disquieting missing persons mystery, accelerating into an eco-thriller with an ending that rivals *Fight Club* in wild ambition.

Itäranta's work is usually categorised as Finnish Weird, a kind of speculative fiction that cuts across genres, hybridising and blurring them into a new form. Itäranta certainly cuts a diagonal swathe across Kim Stanley Robinson, Carlos Castaneda and Philip Pullman, to name a few, and also takes cues from plenty of literary fiction.

Nonetheless, I prefer to see *The Moonday Letters* in the category of "solarpunk" – at the risk of putting some of its exponents to shame. After all, Itäranta's book does what solarpunk should do: it presents a bold vision, with a road map, and, crucially, it clarifies what hope is and what it can do. Hope isn't a luxury of 1950s and 1960s future-euphoria, but a duty, without which we can't reach escape velocity from the reality of our worst fears. It may be immaterial, similar to the animal spirits that 17th-century philosophers believed actuated our muscles and senses, but it is real. You do have to choose to flex that muscle, though. ■



Book
The Moonday Letters
Emmi Itäranta
Titan

Sally also recommends...

Book
A Prayer for the Crown-Shy
Becky Chambers
Tordotcom

Another entrant in the "Hopepunk" category. Where Itäranta tackles the weight of grief keeping us in the Anthropocene, Chambers looks at the characteristics that led humans into that unofficial epoch. Her works are a road map for a sci-fi genre that doesn't rely on the base plots of resource, status, greed and boobs – a project that seems very much worth undertaking.

THE culture on Europa is so different from anywhere else in the solar system that visitors need to be carefully briefed during the inbound journey.

The settlements established on the Jovian moon – domes built in the ocean deep beneath its frozen surface – are shielded from the harsh radiation of space by a thick crust of ice. A crack anywhere would be devastating and the ice is sensitive to sound, so decibel levels are tightly controlled. The result is a colony wrapped in deep, meditative silence, all the better to observe Europa's native life, giant tardigrades that can be seen undulating in the freezing oceans.

In Emmi Itäranta's latest book *The Moonday Letters*, humanity has learned to adapt to the unique environments of other habitats in our solar system – in part due to the devastating consequences caused by trying to force Earth's environment to adapt to us.

Her book opens on the eve of a bigger cataclysm, one so monumental it will propel Earth out of the Anthropocene. It is 2168, and though we have settled

the solar system, our planet is almost uninhabitable – but not empty. Earth natives work what is left of our drowned and poisoned home, which has been largely turned into resort islands where off-worlders come to experience the cradle of humanity they never knew. These resorts are pastiches of the present day – frozen-in-time

"Hope is not a luxury, but a duty, without which we will never reach escape velocity from our worst fears"

Disneylands with names like Hollywoodland or Winterland.

While the slow clean-up work, including plastics processing using algae to produce biogas, pays better than the theme parks, it leaves the workers' lungs in ruins. But they can't leave because visa requirements are stringent. Earthlings are the refugees no one wants, yet their resources feed the off-Earth colonies into which the privileged have now moved, such as Mars, Enceladus and Europa.



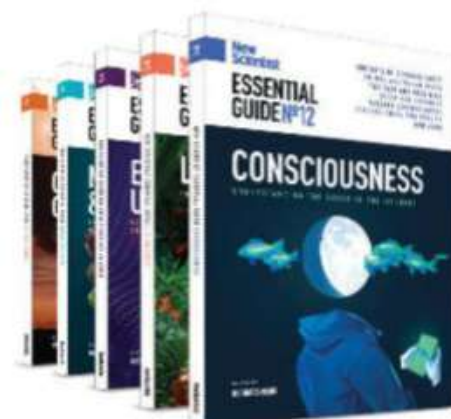
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PLANETS AND PLANETARY SYSTEMS

STARS

GALAXIES

THE UNIVERSE BEYOND

PLANETS AND PLANETARY SYSTEMS

We start close to home. Given the vastness of the universe and the number of stars it contains, it would take a peculiarly blinkered view to believe that our solar system, with its ordered retinue of eight planets, is the only such collection of worlds in our galaxy. Only in the past three decades, however, have our telescopes been able to see planets orbiting other stars, known as exoplanets. We have now discovered more than 5000 of them, and most don't look anything like home.

HOT JUPITERS

The surprises with exoplanets started in 1995 with 51 Pegasi b, the first planet to be discovered orbiting a main sequence star, the most common type of star in the galaxy, other than the sun. At about half the mass of Jupiter, but orbiting closer to its star than Mercury does to our sun, it was the first so-called hot Jupiter – a gas giant that orbits scorchingly close to its host star.

We have since found over 1500 hot Jupiters, and the consensus is these planets have migrated in towards their star after forming in a more distant orbit. But while this is a large proportion of the 5000-odd exoplanets found so far, we shouldn't overestimate how common they are. Most exoplanet detections happen by looking at how a star's light dips or changes colour as a planet passes in front of it, which biases discoveries towards large, fast-orbiting planets that transit across the face of their star more often. "Hot Jupiter planets are relatively rare," says Beth Biller at the University of Edinburgh, UK.

ROCKY PLANETS

We have found far fewer rocky exoplanets, most of which are less than twice the mass of Earth, compared with any other kind: fewer than 200 so far. This may be due to bias caused by the way we detect exoplanets

(see "Hot Jupiters"), or it could be that our own solar system is unusual compared with others in our galaxy. But in the search for alien life, these are exciting planets, especially those that orbit in the "habitable zone", at a distance from their star that would allow liquid water to exist on the surface. A particularly promising location is the TRAPPIST-1 system, which has seven rocky planets orbiting the same star (see right).

NEPTUNE-LIKE

These are around the same size as Neptune and Uranus, with similar hydrogen and helium atmospheres and rocky cores. So far, we have discovered over 1700 of these Neptune-like exoplanets. In 2017, astronomers detected water vapour in the atmosphere of a planet called HAT-P-11b.

SUPER-EARTHS

Of the exoplanets that have been discovered, only a handful are rocky planets like Earth or Mars. Just under a third are gas giants, like Jupiter and Saturn, and just over a third are Neptune-like. The rest are mostly super-Earths, planets that are unlike any in our solar system. These are between twice and 10 times the mass of Earth. Some are made of gas, some are rock and some are formed of a mix of both.

ODDBALLS

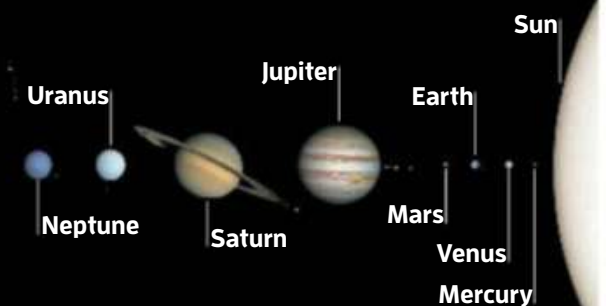
A selection of anomalous cosmic objects and phenomena

WASP-76b

This huge hot Jupiter is twice the size of our Jupiter and hot enough to melt iron – at least on the side that always faces its host star. On this "day" side, it reaches 2200°C, turning iron into a gas. When this gas eventually reaches the nightside of the planet, it cools back to liquid and rains down on the surface.

EARTH

Earth has an unusually large moon compared with the size of the planet. It is also the only planet known to sustain life.



THE SOLAR SYSTEM

Our solar system is home to eight planets: four rocky planets close in, then two gas giants, and finally two ice giants. When we first started exploring exoplanetary systems, we assumed all solar systems would look like ours. But the more systems we discover, the more we realise our own, with its peculiar configuration and formation history, is the unusual one.

TRAPPIST-1

Of the seven planets we know about in the TRAPPIST-1 system, three orbit the star in the habitable zone, where liquid water might exist on their surface, and some of these may have atmospheres. What makes the system particularly unusual is that all of its planets are made from rock. Since Earth is also rocky, TRAPPIST-1 is a promising candidate in the hunt for alien life.

NASA/ESA/CACTISTACINGCRANE CC BY-SA 4.0

UNKNOWN

A selection of some of the things we are still trying to figure out

EXOMOONS

We know of 213 moons – all of them in our solar system and none elsewhere. Our gas giants have the most: Jupiter and Saturn both have 53 official moons, although Saturn also has 29 small “provisional” moons awaiting confirmation. Saturn’s largest moon, Titan, is bigger than the planet Mercury and is the only body other than Earth in our solar system where water cycles between clouds, rain and seas. This



An artist's impression of a moon orbiting a planet beyond our solar system

makes exomoons promising candidates in the search for life beyond Earth.

When it comes to moons in other planetary systems, however, none has been detected with confidence. One study in 2020 identified eight potential exomoons, but they need to be observed for a little longer to say for sure that they exist. Exomoons are detected in the same way planets are detected – for example, the transit method that looks for a dip in the light from a star as a planet moves in front of it. But these dips are much smaller for moons than planets. “Ultimately, it is the smallness of exomoons that makes them so hard to detect,” says Paul Weigert at Western University in Ontario, Canada.

ROGUE PLANETS

Some planets exist entirely without stars. These lonesome objects are often called sub-brown dwarfs because they are thought to have emerged from the collapse of clouds of dust and gas in a similar way to the formation of stars and brown dwarfs (see “Stars”, right) – but they were too small for any fusion to occur.

One of the handful we know about, WISE 0855, sits by itself in space just over 7 light years away from Earth. Its mass is estimated to be between three and 10 times the mass of Jupiter, water ice has been found in its atmosphere and its temperatures can reach as low as -48°C . That is the coldest atmosphere we have detected outside our solar system, perhaps giving us insights into what the atmospheres of other similarly cold planets look like.

SPACE ROCKS

In our solar system, the processes of planet formation left quite a few offcuts. These cluster in two known regions and one hypothetical place. The known regions are the asteroid belt between the orbits of Mars and Jupiter, whose 20,000-odd rocky bodies range from just a few metres across to the dwarf planet Ceres, which is almost 950 kilometres in diameter; and the Kuiper

belt beyond Neptune, whose most famous resident is the dwarf planet Pluto, which is some 1 200 kilometres across. There is also a small group of co-orbital asteroids, which share their orbits with planets. One even shares Jupiter’s orbit despite going the opposite way around the sun.

The hypothetical home of space rocks is the Oort cloud, a spherical cloud of icy rocks encircling the solar system, whose existence is hypothesised as a source for the long-period comets that sometimes swing by the sun on their highly elliptical orbits.

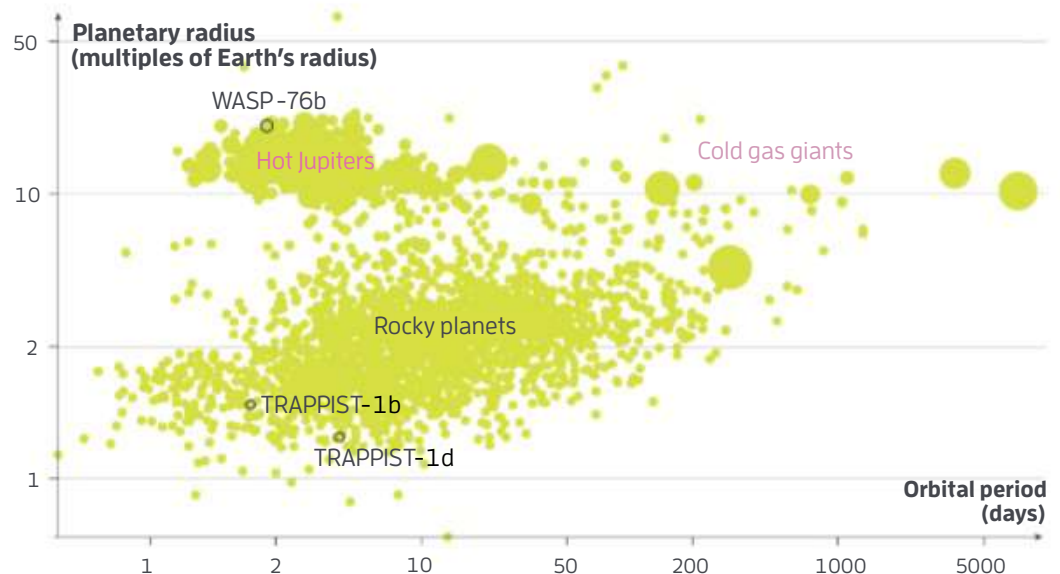
A suspicion that similar regions exist in other solar systems has been increased by the identification in recent years of two interloping bodies from outside the solar system, ‘Oumuamua and the comet 2I/Borisov. There are hints that a further 17 such interlopers may reside in our cosmic neighbourhood.

Q. HOW ARE PLANETS MADE?

After stars form, a ring of dust is left around them. This dust slowly collects together in clumps, which pull more dust into them. Some break apart, while others stick together. Eventually, enough clump together to form something called a planetesimal. Far away from the star, these can freeze and form icy planetary cores that can draw gases in by slowing them down. Closer towards the star, there isn’t much gas left over and so rocky planets form.

Exoplanet explosion

Since the first discovery of a planet orbiting another sun-like star in 1995, astronomers have identified 5060 exoplanets. Here, the size of the circles represent the mass of the planets



SOURCE: exoplanets.nasa.gov/discovery/exoplanet-catalog/



STARS

To our eyes, stars are the most obvious feature of the universe, and they are undoubtedly important. These nuclear fusion reactors created the elements that make up our bodies and the planet we live on, and one produces the heat and light that life on Earth needs to survive. But to fixate on just our own sun would be to deny the magnificent diversity of stars in all their stages of birth, life and death.

GIANTS AND SUPERGIANTS

Once a star begins to exhaust its primary hydrogen fuel, it starts to fuse heavier elements in its core, while still fusing hydrogen into helium in its outer regions. This causes the star to expand, and leave the main sequence. What happens next depends on how large it was to begin with. When the Danish astronomer Ejnar Hertzsprung started categorising stars, he realised expanding stars fell into two categories: main sequence stars and other, distinctly larger stars, which he called giants. A few years later, an even larger category appeared, and was given the name supergiants. A few stars under a fourth category of hypergiant have since been identified, including UY Scuti, which is around 1 700 times larger than our sun.

BINARY STAR SYSTEMS

A binary star system is a pair of stars that are gravitationally bound to and in orbit around one another. 55 Cancri, found 4.1 light years from Earth in the constellation Cancer, is one example. The fifth planet orbiting 55 Cancri is twice the size of Earth, and made of diamond.

WHITE DWARFS

After a giant star has run out of hydrogen to burn, it begins to fuse helium to make carbon and oxygen. As these elements begin to build up, for most stars, the core temperature isn't high enough to take fusion any further and so it stops. At this point, the gravitational pull ➤

MAIN SEQUENCE STARS

Not all stars shine as brightly or are the same colour. They are classified by the relationship between their temperature and the amount of light they give out. Hotter stars shine bluer, while cooler stars shine redder. Across this spectrum, however, stars have a huge range of brightness, from one ten-thousandth the sun's luminosity to a million times brighter than the sun. The biggest factor in a star's luminosity is its mass, which depends on the amount of material present when it formed.

Astronomers plot these variables on a Hertzsprung–Russell diagram (see "The diversity of stars", page 40), with stars appearing in different places at different stages of their life. Stars in the prime of life, during which time they are burning by fusing hydrogen nuclei into helium, are called main sequence stars and fall on a diagonal line from massive, hot blue stars to small, cool red ones. The very smallest and coolest main sequence stars are red dwarfs, with masses less than a tenth that of our sun.

5060

THE NUMBER
OF CONFIRMED
EXOPLANETS*

3793

EXOPLANETARY
SYSTEMS*

*Figures correct at time of going to press

inwards is no longer balanced by an outward pressure from the nuclear reactions in the core and the star implodes to become a white dwarf. These remnants of dead stars are dim and dense, with hundreds of thousands of Earth masses packed into the volume of our planet. They only shine thanks to leftover heat.

SUPERNOVAE REMNANTS

The very biggest supergiant stars don't become dim white dwarfs. Their core temperatures are sufficient to fuse nuclei right up to iron, and they end their lives in dramatic explosions – called supernovae – to leave behind black holes or neutron stars.

At the heart of the Crab Nebula sits a relatively young neutron star, left over from a supernova that was seen from Earth in AD 1054. At the time, Chinese astronomers noted it as a “guest star” near the constellation Taurus that became four times as bright as Venus in the sky, before disappearing. Astronomers realised in 1939 that this supernova must have been where the Crab Nebula is and began hunting for the star. In 1968, when astronomers finally found the neutron star, called the Crab Pulsar, it was the first known supernova remnant.

NEUTRON STARS AND PULSARS

We know of around 2000 neutron stars, collapsed remnants of supergiant stars that aren't quite large enough to form black holes. The heaviest neutron star is 2.1 times the mass of the sun. They are the densest stars ever seen, with the mass of our sun packed into a sphere around 10 kilometres across.

Some neutron stars spin incredibly fast on their axis, with a jet of intense radio emissions whirling round with them like the beam from a lighthouse. These are called pulsars, and were discovered by astrophysicist Jocelyn Bell Burnell in 1967.

BLACK HOLES

Stellar-mass or astrophysical black holes are created when a massive star, with at least 20 times the mass of the sun, runs out of fuel in its core. If the core is above three solar masses, it collapses to form a black hole. Only around a couple of dozen such black holes have been observed in our galaxy, but astronomers believe hundreds of millions exist in the Milky Way alone. We

Q. HOW MANY STARS ARE THERE?

In December 2021, the Sloan Digital Sky Survey released the biggest ever census of stars in our galaxy, having studied the spectra of 700,000 individual stars. But there are plenty more out there. In the Milky Way alone, there are an estimated 100 billion stars, and beyond our own galaxy there are billions of other galaxies. This means there are thought to be around 200 billion trillion stars in the universe.

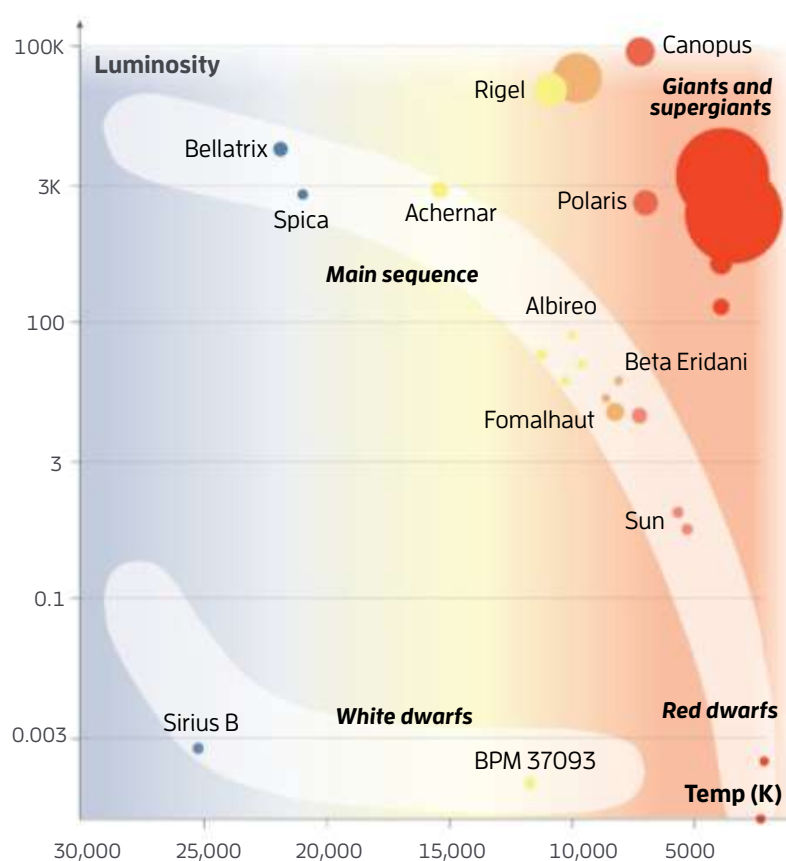


NASA/ESA/HEIC AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

A supernova remnant called N 63A, in a nearby galaxy

The diversity of stars

Stars evolve with time, and astronomers can trace that evolution by plotting the temperature of any given star against the amount of light it gives out, known as luminosity



can't see them directly: their gravitational pull is so strong nothing, not even light, can escape. Instead, we infer their presence from watching how nearby stars and galaxies move, and by signals produced by their collisions, called gravitational waves.

The existence of black holes was predicted by Albert Einstein's general theory of relativity as entities whose immense gravity would cause space-time to curve infinitely, creating what became known as a singularity. But here, general relativity breaks down: the solutions to the equations go to infinity. Many physicists believe these singularities don't describe what is happening inside real black holes, and instead are a sign that we need to amend our theories.

The question is how. A theory that would accurately describe black holes would need to blend general relativity with quantum theory, our description of matter on the smallest scales – a trick no one, as yet, has been able to pull off.

ODDBALLS

PROXIMA CENTAURI

Red dwarfs – the smallest and coolest star on the main sequence – are the most common star in our part of the Milky Way, although none is visible from Earth with the naked eye. They include the closest star to us, Proxima Centauri, which is 4.2 light years away. It is one of the estimated 10 per cent of stars in the Milky Way that are part of a triple star system. In addition to Proxima Centauri, its system consists of two larger stars, known as A and B, which orbit each other at an average of 23 astronomical units (AU), the distance from Earth to the sun. A is a little larger than the sun and B is slightly smaller than the sun. Proxima Centauri is the third star in the system, and orbits much further out – around 10,000 AU.

TABBY'S STAR

In 2015, citizen scientists spotted a main sequence star 1470 light years from Earth that repeatedly dips in brightness by up to a quarter over several days. Many hypotheses have been put forward to explain the behaviour of KIC 8462852, also known as Tabby's Star, including that the dimming might be caused by an orbiting alien megastructure. More prosaically, it might just be down to the effects of a large amount of dust swirling around it.

UNKNOWN

POPULATION III STARS

The very first stars in the universe are thought to have been a group called population III stars, although we don't know for certain they exist. The idea is that they must have been made entirely from hydrogen and helium left over from the big bang, and died quite soon after being formed, leaving a lot of hydrogen and helium behind to form a new generation of stars. Because they are so old, searching for population III stars involves looking deep into the past, but there is hope that with new space and ground-based telescopes, such as the James Webb Space Telescope, we might soon get closer to seeing them.

NASA, ESA, NRAO AND L. FRATTARE (STSCI)



GALAXIES

Every star we see in the night sky is part of just one galaxy – our own Milky Way. Up until around 100 years ago, astronomers believed this was all there is. Now we know the Milky Way is just one of billions of galaxies in the universe, if not more: NASA estimates there could be 2 trillion.

SPIRAL GALAXIES

The vast majority of the 300 million or so galaxies we have observed have been looked at using ground-based telescopes, and appear mainly as unresolved blobs. Where we can make out some detail, we see that around 60 per cent take on the distinctive form of a spiral galaxy: a flat disc of stars made up of a central bulge surrounded by arms arranged in a spiral shape. In normal spiral galaxies, these arms extend directly from the galaxy's core; barred spirals, meanwhile, have a central bar and the spiral arms stretch out from its ends (see "Galaxies galore", page 42). Spiral arms only form in galaxies that are disc-shaped, but exactly why some galaxies are spirals and some aren't isn't fully understood. Some form arms because of a nearby source of gravity, but not all spiral galaxies have such a mass nearby. It is thought that spiral galaxies evolve into elliptical galaxies.

ELLIPTICAL GALAXIES

About a third of all the galaxies we have seen are classified as elliptical. These usually form when spiral galaxies merge together, so their shape can vary depending on the ways they merge and collide – some look almost circular, while others are much more elongated. The stars in elliptical galaxies tend to be older than in spirals because of this.

IRREGULAR GALAXIES

Galaxies that don't have a clear spiral or elliptical structure are called irregular galaxies. Most of these are dwarf galaxies, small galaxies composed of a few billion stars, and they are more easily pulled apart by external gravitational forces. However, some regular-sized galaxies are irregular in shape, too, which is usually as a result of collisions with other galaxies.



ODDBALLS

THE MILKY WAY

If we were able to observe the Milky Way from outside, we would see that it is a pretty standard, mid-range spiral galaxy containing a few hundred billion stars. But it won't always stay that way. Our galaxy is on a collision course with Andromeda, which became the first galaxy other than our own to be discovered when, in 1925, Edwin Hubble confirmed it was, in fact, a galaxy. When this enormous crash occurs, it could result in an elliptical galaxy. The Milky Way is odd in other ways too. For one thing, it has far fewer dwarf galaxies nearby in space than our models predict.

NGC 1275

Even with the category "irregular", not all galaxies fit neatly into any classification scheme (see "Galaxies galore", below right). NGC 1275 is the central galaxy in the Perseus cluster and the brightest known X-ray source in the universe. It is elliptical, but has a spiral pattern when studied under certain wavelengths of light, has a massive central core including a supermassive black hole, and has long filaments extending from it that are more than 10 times the length of a normal galaxy. It also has a galaxy merging with it. "It essentially has everything, and we don't understand it," says Christopher Conselice at the University of Nottingham, UK – a reminder of how complex galaxies can be and how much we still have to learn.

HD1

A galaxy discovered in April 2022, called HD1, is about 33.4 billion light years away, making it the most distant object ever seen.

SAGITTARIUS A*

The supermassive black hole at the heart of our own galaxy is 4 million times the mass of the sun. At first, its presence was inferred by studies of the way stars in the centre of the galaxy move. One star in particular, called S2, was observed for 27 years and these observations were used to prove that Isaac Newton's laws of gravity couldn't describe its motion, but Albert Einstein's general relativity could. Then, in May 2022, the first ever picture of it was released. Again, the image showed relativity was right.

SATELLITE GALAXIES

Some dwarf galaxies are held within the gravitational field of a nearby, larger galaxy. The Milky Way has 14 confirmed satellite galaxies, including the Large Magellanic Cloud, the Small Magellanic Cloud and the Sagittarius dwarf galaxy. The last of these is thought to have collided with the Milky Way at least three times in its history, and one of these events may even have triggered the formation of our solar system.

THE INTERSTELLAR MEDIUM

The vast space between stars within a galaxy isn't totally empty, even though parts of it are the closest thing to a vacuum that we know of in the universe. In the interstellar medium there is an average of one atom in every cubic centimetre of space, a tiny fraction of the 90 million trillion atoms found in the same volume of air at ground level on Earth.

Most of the atoms in the interstellar medium – about 99 per cent – are hydrogen atoms from dying stars. But over the past decade or so, we have spotted an ever-growing menagerie of other atoms and molecules, including helium hydride, one of the first molecules predicted to form in the universe from reactions between hydrogen ions and neutral helium atoms, and argonium, formed of hydrogen and

the normally unreactive noble gas argon.

One striking fact is that the interstellar medium is everywhere, indicating that galaxies don't form new stars at a high enough rate to deplete its diffuse contents. Studying processes within it can therefore help us understand how stars form – and how they don't.

SUPERMASSIVE BLACK HOLES

Most galaxies are believed to host a black hole millions of times the mass of the sun at their centre. These supermassive black holes are thought to be created by the merger of smaller astrophysical black holes (see page 40). But we have spotted some in the early

Q. HOW DO GALAXIES FORM?

Galaxies start off as clouds of gas, stars and dust with little structure. They begin to form into coherent arrangements as they clash and merge with other galaxies, all of which is driven by the pull of gravity from visible matter, black holes and dark matter (see page 44). In the past few years, astronomers have been improving computer simulations that model how the Milky Way and other galaxies formed, some of which have shown that stars form more slowly than we first thought.

Galaxies galore

Galaxies are classified according to their appearance, with spirals by far the most common, though there is plenty of variety within each category

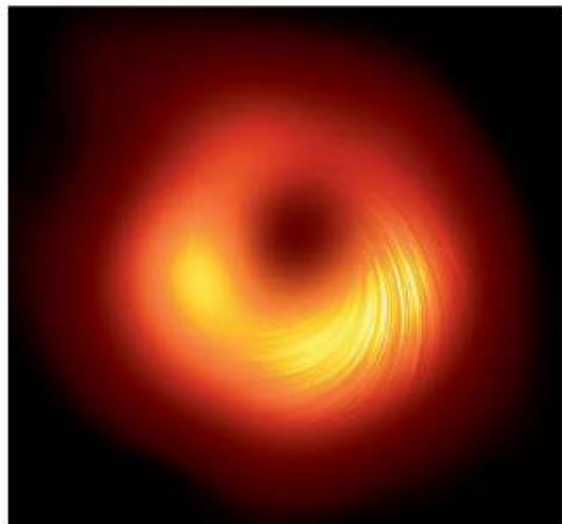
Elliptical

Irregular

Spiral

Barred spiral

VECTORTATU/GETTY IMAGES



**Behold the
black hole at
the heart of
galaxy M87**

universe, when it was just 700 million years old. This is a problem because, according to our models, supermassive black holes shouldn't have been able to form so fast.

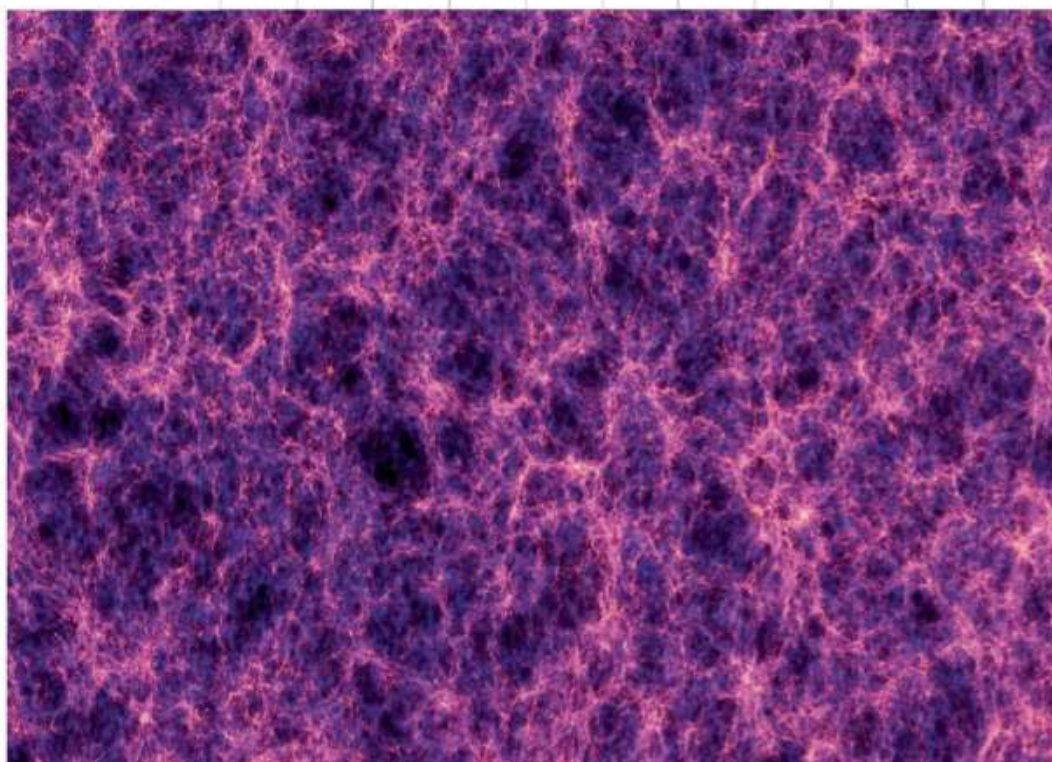
Mostly, we infer the presence of supermassive black holes from the gravitational effects on their surroundings. In 2019, however, astronomers at the Event Horizon Telescope released the first ever picture of a black hole, the one at the centre of the M87 galaxy. In May 2022, the same group released a picture of Sagittarius A*, the black hole at the centre of the Milky Way.

It is easy to portray supermassive black holes as voracious monsters consuming all matter within reach, but that isn't necessarily the case. "Very often supermassive black holes don't do much, sitting passively in the heart of their host galaxies for billions of years," says Philippa Hartley at the SKA Observatory, a project to build the world's largest radio telescope.

ACTIVE GALACTIC NUCLEI, QUASARS AND BLAZARS

Sometimes matter spirals into supermassive black holes, where it is promptly shredded and superheated. This results in active galactic nuclei, some of which throw out giant jets of charged particles that stretch beyond the host galaxy. They make for a dramatic show, if we happen to be in the firing line.

When they were originally discovered as bright, point-like objects in radio frequencies, active galactic nuclei received the name "quasi-stellar radio object" or quasar. Now, this refers to any particularly bright active galactic nucleus, while those with jets angled towards Earth are called blazars.



VOLKER SPRINGEL (MAX PLANCK INSTITUTE FOR ASTROPHYSICS) ET AL.

THE UNIVERSE BEYOND

Galaxies don't exist in isolation. Taking a more expansive view reveals the overall structure of stuff in the universe – providing clues as to its origin and evolution.

~300^{MILLION}
**GALAXIES
OBSERVED**

Source: The Dark Energy Survey

~100^{BILLION}
**STARS IN THE
MILKY WAY**

CLUSTER, SUPERCLUSTER

If you could zoom out of the Milky Way, you would start to see the Local Group – a collection of at least 80 galaxies set in a dumb-bell shape. At one end is the Milky Way and its satellite galaxies, and at the other is our closest large neighbour, Andromeda, and its satellites.

Zoom out a bit further and you would see that the Local Group is next door to a cluster of thousands of galaxies called the Virgo Cluster. That cluster and the Local Group are both, in turn, part of a much larger structure that is more than 100 million light years across and contains another 100 groups of galaxies, called the Virgo Supercluster.

Astronomers believe there to be some 10 million such superclusters in the observable universe. And yet a study in 2014 indicated that the Virgo Supercluster is part of an even bigger supercluster called Laniakea, showing that the universe is ordered on a much larger scale than we originally thought. ➤

ODDBALLS

THE GREAT ATTRACTOR

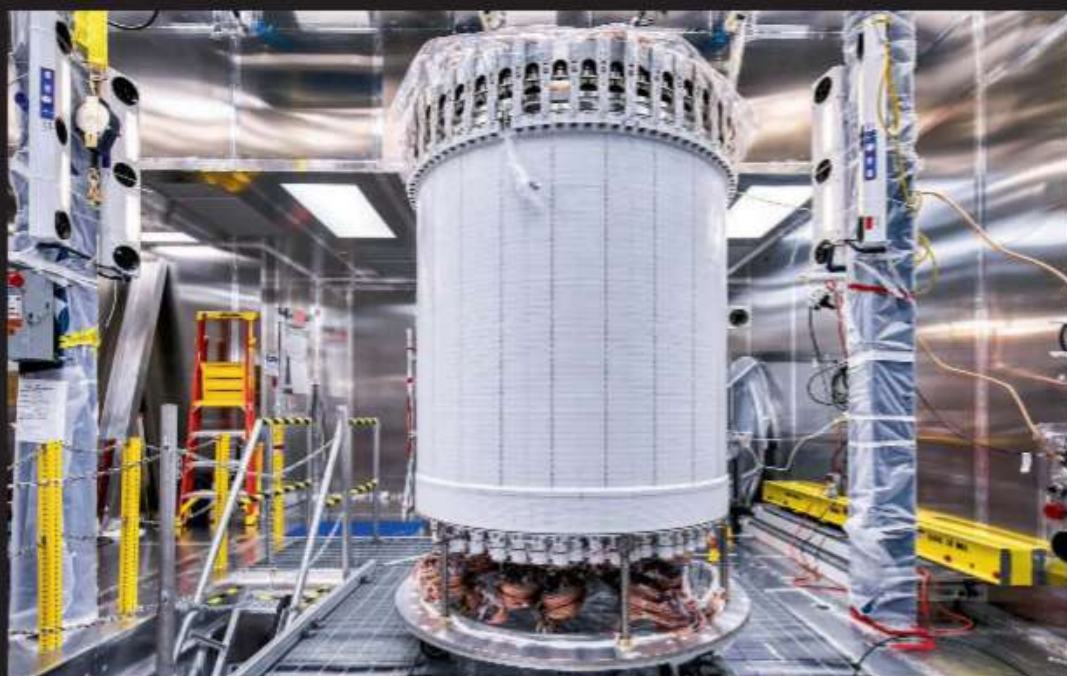
A few decades ago, astronomers looking for elliptical galaxies noticed that the Milky Way and other galaxies were being pulled towards a concentration of mass called the Great Attractor, which lies at the centre of the large Laniakea Supercluster. It is estimated to contain more than 10 million billion times the mass of the sun and lies about 150 million light years away.

Estimated, because the Great Attractor lies in what is known as the Zone of Avoidance – a portion of the sky that is obscured from view by the dust and stars within our own galaxy. This makes the Great Attractor a tricky object to study, and what it is remains a mystery.

THE GREAT WALL

Also known as the Hercules–Corona Borealis Great Wall, the Great Wall is the largest known structure in the observable universe that is made up of groups of galaxies. It is 10 billion light years in length, more than 10 per cent of the width of the observable universe itself.

It is the largest of several such walls observed in recent years that challenge the cosmological principle. This says that, viewed on a large enough scale, the universe looks the same on average. It was introduced as a simplifying assumption to tame the fiendishly complex equations of Albert Einstein's general relativity, which govern the make-up and evolution of the universe. If it were to fall, the consequences would be huge. "The cosmological principle is the foundation upon which the theoretical framework of cosmology is assembled," says Roger Clowes at the University of Central Lancashire, UK, who discovered two of the biggest walls we have ever observed.



The LUX-ZEPLIN dark matter detector in South Dakota

UNKNOWN

DARK MATTER

More than 80 per cent of the matter in the universe comes in a form we can't see. The existence of this "dark matter" was postulated in 1922 when astronomer Jacobus Cornelius Kapteyn studied the velocities of stars. Then, in the 1930s, astronomer Fritz Zwicky came to a similar conclusion when studying galaxy clusters. Observations by Vera Rubin in the 1970s confirmed something similar about the rotations of individual galaxies, suggesting galaxies are kept together by an encircling halo of dark matter.

There are lots of suggestions for what dark matter could be, from an invisible sea of WIMPS, or weakly interacting massive particles, to MACHOS. These massive astrophysical compact halo objects would be much meatier bodies made of ordinary matter, perhaps primordial black holes – a theoretical type of black hole thought to have been created in the universe's first few moments. But dark matter's true nature remains a mystery. "We know a bunch of things that it isn't," says Seshadri Nadathur at the University of Portsmouth, UK.

An artist's impression of the Hercules–Corona Borealis Great Wall

DARK ENERGY

Dark matter far outweighs normal matter, but dark energy outguns both of them together. The latest figures suggest it accounts for 68 per cent of all the stuff in the universe. Just don't ask what it is, because we have no idea.

What we can say is what dark energy does. If dark matter is an invisible glue holding galaxies and galaxy clusters together, dark energy works in the opposite way, accelerating the growth rate of the universe and making it expand ever faster as time goes on.

Dark energy was discovered in the late 1990s through observations that showed distant supernovae were further away than we expected, and its effects have been confirmed by, for example, studying temperature patterns in the earliest radiation in the universe, known as the cosmic microwave background. One possibility is that dark energy is created by quantum particles popping in and out of existence, while another is that it is caused by a "quintessence" – a completely new force of nature we haven't yet discovered. A project called the Dark Energy Survey hopes to find some answers by better mapping distant galaxies and the history of the universe's expansion.



THE COSMIC WEB

The structure of the universe doesn't stop at superclusters. Zooming out from the Virgo Supercluster, you would see the Pisces-Cetus Supercluster Complex. This is a galaxy filament, or a vast thread of superclusters. At its largest scales, the universe is made up of these filaments, which spread out like a web with voids of space in-between.

The cosmic web is the largest known structure in the universe, and we observed it directly for the first time in 2019. Its structure is thought to have been governed by strings of dark matter that attracted normal matter, in the form of superclusters, to congregate along the filaments. The voids in-between contain few or no galaxies, and can stretch for distances of 30 to 300 million light years.

LYMAN-ALPHA BLOBS

While filaments in the cosmic web are the biggest structures in the universe, they can be broken down into smaller galaxy clusters and galaxies. The biggest individual objects in the universe are huge clouds of gas, some of which are more than 400,000 light years across. Called Lyman-alpha blobs after a spectral line of hydrogen seen in the light they emit, the process that makes these huge clumps of hydrogen gas is a mystery.

Q. WHY DOES THE UNIVERSE LOOK THE WAY IT DOES?

In 1982, physicist Stephen Hawking realised that, during a period of breakneck expansion known as cosmic inflation that is thought to have occurred at the big bang, random quantum fluctuations in energy density would happen that over the next 13.8 billion years would grow into large-scale structures.

The exact topology of matter this process would cause the universe to have today has been the subject of debate. In 1986, J. Richard Gott at Princeton University and his colleagues used cosmological simulations to predict that, if large-scale structure in the universe was due to early quantum fluctuations, it would look truly random, like the structures and holes in a sponge. Since then, observations of the vast structure of galaxy clusters known as the cosmic web (see "The cosmic web", left) have confirmed it is sponge-like in its shape, suggesting its filaments are the fossil remnants of random quantum fluctuations that formed in the first 10 to 35 seconds of the universe. "Not only are they the largest things in the universe," says Gott, "but also they are the oldest things in the universe."

"THE GREAT WALL IS 10 BILLION LIGHT YEARS IN LENGTH"

THE COSMIC MICROWAVE BACKGROUND

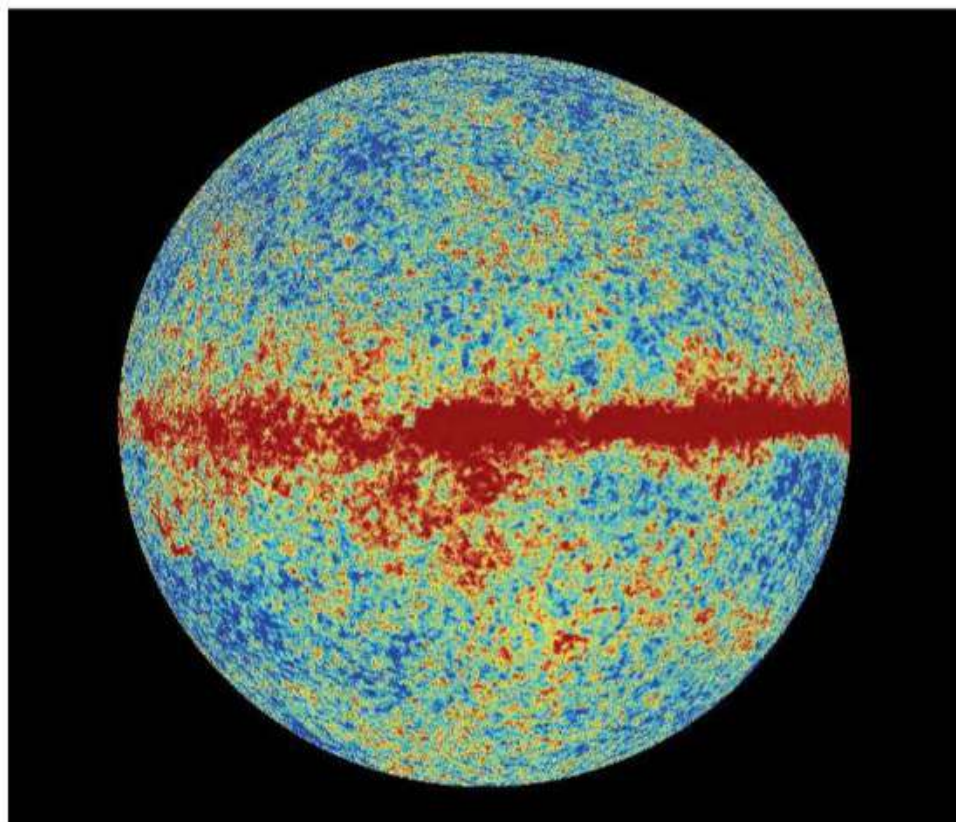
After the big bang, the universe was so hot that all the electrons escaped their protons and the universe therefore became a huge lump of plasma. At this time, photons couldn't go very far without being scattered by electrons, making the universe "opaque". Then, about 370,000 years after the big bang, the universe cooled enough that the electrons became bound to protons, creating neutral hydrogen atoms in a process called recombination. After this happened, the photons could travel freely. We still see those photons today, in a faint source of radiation called the cosmic microwave background.

FAST RADIO BURSTS

In 2012, astronomers using the Arecibo radio telescope on Puerto Rico spotted a strange signal – a short, milliseconds-long shower of radio waves coming from outside the galaxy. The signal, which in 2018 was confirmed to be coming from a quasar, was one of the first detected fast radio bursts. Since then, hundreds more have been spotted. Some flash once, others are "repeaters". Explanations for these strange signals have ranged from aliens to black holes and moving clouds of dust.

GAMMA-RAY BURSTS

These blasts of high-energy radiation make their way towards Earth from all directions and are thought to be triggered by certain stars exploding in supernovae. Gamma-ray bursts are the most energetic explosions since the big bang, and were first spotted in the 1960s when the US was searching for signs that the Soviet Union was attempting secret nuclear tests. ■



The earliest radiation in the universe, known as the cosmic microwave background



Abigail Beall is a features editor at New Scientist

The dark side of daydreaming

Mind wandering can be fun and surprisingly rewarding, but it has a sinister side too. **Eric Taipale** reports

JAYNE BIGElsen was always a daydreamer. As a young child, TV fuelled her imagination. “I would watch certain shows over and over... and I would create my own episodes,” she says. She found daydreaming an effective way to dispel boredom. However, by her teens, Bigelsen’s fantasy world had become more all-consuming. “The first thing I would do when I woke up in the morning is continue one of my stories,” she says. “I remember being frustrated when I ran into a friend because I had to stop my story and talk to them.”

Everyone knows the pleasures of daydreaming. Whether envisioning your next vacation or an ideal romantic partner, it is enjoyable to let your mind drift into a stream of consciousness where aspirations come alive. Better yet, research shows that, far from being a waste of time, daydreaming has all sorts of benefits and is particularly important for developing brains. That’s just as well, because we spend lots of time doing it. Two-thirds of children have imaginary friends. One in 10 invent fantasy worlds, or “paracosms”. And when psychologists tracked the mental states of 15,000 volunteers, they found that adults spend around half their waking hours daydreaming.

Nevertheless, you can have too much of a good thing. As Bigelsen discovered, excessive daydreaming can undermine one’s ability to cope with everyday life. Psychologists call this maladaptive daydreaming. They believe it can be addictive and its prevalence increased

during the covid-19 pandemic. Much about this condition remains a mystery, but we are starting to discover who is prone to it, what causes it and how it can be managed.

Daydreaming was long considered a distraction – quite literally – from the main purpose of thinking: focus. The ability to concentrate is essential for solving analytical problems. What’s more, our brains contain an “executive control network” that links various areas responsible for keeping us on task and regulating impulses. However, in the 1990s, researchers using brain scanners noticed another network of neurons, one that fired up when people weren’t thinking about anything in particular. We now know that this “default mode network” performs various mental housekeeping tasks, such as sorting and filing memories. It is also the part of the brain most active when we daydream.

Thinking is a constant tug of war between these two networks. That makes sense in evolutionary terms because our survival isn’t just dependent on focus. Daydreaming allows us to move mentally in time and space, planning for the future and rehearsing different possible scenarios. It is also crucial for creativity and lateral thinking, where the brain makes connections between disparate bits of information whose links aren’t apparent when we are too focused. When we intentionally let our minds wander, the default mode network can even forge connections with the executive control network, increasing our ability to learn.



PATRYK HARDZIE



However, while the benefits of daydreaming were coming to light, clinical psychologist Eli Somer at the University of Haifa, Israel, discovered something different. “At the beginning of the millennium, I noticed that some of my patients were describing extensive fantasy lives,” he says. “These patients had been regulating traumatic experiences by using daydreaming as a soothing mental activity.” That sounds positive, but when Somer probed further, he found that their fantasies were replacing real social interactions and, as a result, were undermining their ability to maintain relationships with friends and family. Psychologists call repetitive actions that interfere with an individual’s ability to cope with daily life “maladaptive behaviours”. And here was a behaviour that not only undermined social relationships, but also had detrimental effects on people’s performance at work and in education. So, in 2002, Somer coined the term maladaptive daydreaming to describe what he had discovered.

What’s the difference?

What began as a study of eccentric daydreaming in six patients has, in the past 20 years, become a mission to understand this strange psychological phenomenon. Even defining maladaptive daydreaming isn’t easy. There have been no brain-imaging studies of the behaviour, so we don’t know whether it differs neurologically from regular daydreaming. And the amount of time an individual spends in their fantasy worlds isn’t necessarily an issue: many people daydream for hours each day without that being a problem. But maladaptive daydreams are qualitatively different.

One person who has helped reveal how, is Bigelsen. Now a successful public-interest lawyer based in New York, in recent years, she has teamed up with Somer and others to explore the behaviour. One of their studies compared 340 self-professed maladaptive daydreamers with controls. The former reported that their daydreams were hard to control and interfered with their lives. They spent an average of 56 per cent of their waking hours in fantasy worlds featuring fictional characters and elaborate plots. Unlike regular daydreams, theirs often involved pacing and rocking or unconscious facial expressions. “At times, the activity is accompanied by ➤



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stereotypical repetitive movements and listening to evocative music to facilitate the immersive state,” says psychologist Nirit Soffer-Dudek at Ben-Gurion University of the Negev, Israel, another pioneer of the field.

Other research suggests that maladaptive daydreaming is so immersive that many people find themselves talking or whispering with imaginary characters. Maladaptive daydreamers spend an average of around 4 hours a day in this zoned-out state. Their daydreams can take many forms, from amusing and surreal to solemn and poignant, but they tend to be more vivid and emotionally intense than regular daydreams. Common themes are love, friendship, self-idealisation, social support and imaginary family, which might help explain why the activity is so compelling. A 2015 study found that daydreaming about significant others

increases feelings of love, happiness and connection. However, the researchers also noted that if such daydreams displace actual social interactions, they could result in loneliness and desperation.

“The waste of time spent in fantasy, and the gap between the idealised imaginary life and the more dreary reality, can result in feelings of shame, depression and attention deficits,” says Somer. Exploring this idea further, he and Soffer-Dudek asked 77 people to keep a diary of the emotions associated with their maladaptive daydreaming. This revealed that the activity brought increases in negative emotions, alongside symptoms of depression, social anxiety and general anxiety, and decreases in positive emotions.

The study also found that obsessive-compulsive feelings consistently preceded bouts of daydreaming, which fits with the idea

“Like addictions, it offers an escape from stress and reality”

Who is at risk?

Maladaptive daydreaming isn’t confined to Western societies. “We have found it to be present in many countries and cultures around the world,” says Nirit Soffer-Dudek at Ben-Gurion University of the Negev, Israel. “And it seems to be more common in young people than older people.” Loneliness, distress and boredom are thought to trigger it. But researchers are discovering more serious risk factors too.

For a start, it is more common among people who have experienced severe trauma, such as sexual abuse as a child. Eli Somer at the University of Haifa, Israel, found that maladaptive daydreamers who were victims of childhood neglect and similar traumas often fantasised about being rescued and saving others from maltreatment, assuming the role of a captor, taking revenge and experiencing other allusions affiliated with death. “Those with

trauma histories such as childhood adversities usually report that their vivid daydreaming abilities enabled them to [mentally] escape from a harsh reality,” says Soffer-Dudek.

Many people who experience maladaptive daydreaming have another psychological condition, including anxiety, depression or obsessive-compulsive disorder. People with a dissociative disorder – a psychological condition where you feel detached from yourself – are at especially high risk.

There is also a link with attention deficit hyperactivity disorder (ADHD). Earlier this year, Soffer-Dudek, Somer and their colleagues reported that around a fifth of respondents with ADHD showed signs of maladaptive daydreaming, with many also expressing feelings of loneliness and reduced self-esteem.

In addition, surveys suggest that maladaptive daydreaming increased

as a result of the covid-19 pandemic. Last year, research reported that during lockdowns, 17 per cent of the more than 6000 Italian adults they surveyed had experienced atypical preoccupations with fantasies consistent with maladaptive daydreaming. And in 2020, Somer and others surveyed people in more than 70 countries and found that they were more likely to struggle with intense and prolonged daydreaming when in lockdown than they were in normal circumstances.



Loneliness and boredom are two triggers for maladaptive daydreams, which might help explain why people were more prone to them during covid-19 pandemic lockdowns



Daydreaming can be harmful when it interferes with work

that maladaptive daydreaming is a behavioural addiction. The scientists who first proposed this in 2018 pointed out that, like many addictive and impulsive tendencies, it offers a temporary escape from stressful thoughts and unfavourable realities. The idea is yet to be fully tested, though.

Addictions are associated with the release of dopamine in the brain, which can produce a euphoric effect. No research has investigated whether this happens during maladaptive daydreaming, nor have there been studies to look for genes known to be associated with the behaviour. However, there is research indicating that maladaptive daydreaming may be common in people with internet gaming disorder, a behavioural addiction recognised in the latest edition of the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5), a US handbook that lays out the vast panoply of diagnosable mental health conditions. Both seem to involve the same impulsive and stress-relieving mechanisms.

All this comes as no surprise to Noam (not his real name), an Israeli student who has been struggling with maladaptive daydreaming. “These daydreams are very tangible, so it’s a very addictive feeling,” he says. “When I was trying to stop, getting back to my real life got me depressed. It’s much more comfortable to be in the safe zone I invented in my head.”

The prevalence of such experiences is unknown because maladaptive daydreaming isn’t listed in the DSM-5 or widely recognised by doctors. Research has revealed that certain people are more prone to it (see “Who is at risk?”, left), but many questions still remain. For example, how does maladaptive daydreaming affect psychological development? “We have received emails from parents describing such behaviours in their children, who then go on to describe their inner worlds when asked what they are doing,” says Soffer-Dudek. “Unfortunately, there are not yet any published studies on children.” Another mystery is the common use of music to trigger daydreams. Somer hopes to find out more about this and discover how music influences the fantasy worlds that people create.

Diagnostic tests

Somer also wants to encourage other psychologists and doctors to take maladaptive daydreaming seriously. “Many professionals object to pathologising daydreaming,” says Somer. “But they seem to forget that alcoholism is not an unnecessary pathologising of social drinking or that obsessive-compulsive disorder is not merely another form of orderliness.” He has developed the Structured Clinical Interview for Maladaptive Daydreaming,

which aims to help medics assess whether someone is experiencing maladaptive daydreaming. Another test, the 16-item Maladaptive Daydreaming Scale, can be used to gauge the severity of the condition. This evaluation measures aspects of daydreaming, such as how comforting it is, how difficult it is to control, how disruptive of everyday activities it is and to what extent it is triggered by music or accompanied by repetitive movements and facial expressions.

As you would expect for a condition that isn’t yet widely recognised, treatment and management options are still being developed and tested. People who experience maladaptive daydreaming often have underlying mental health conditions and other stressors, and addressing these through general psychotherapy could have a big impact, says Soffer-Dudek. “Monitoring the behaviour, its triggers, conditions and emotional consequences may help individuals control it,” she says. “Also, practising mindfulness meditation may be helpful in staying in the present rather than escaping to fantasy worlds.” Mindfulness meditation is a mental exercise that encourages stress reduction by refocusing the mind on specific things without judgement. Other techniques involve recording occurrences of maladaptive daydreaming and suspected triggers in a journal, and rewarding personal milestones in suppressing these fantasies.

Bigelsen is proof that maladaptive daydreaming can be managed. She was diagnosed with obsessive-compulsive disorder years ago and believes that the medication she takes to cope with that has helped her control her daydreaming too. Noam is also doing well. Just two months after starting treatment with Somer, his daily daydreaming has fallen from 16 hours to around 7 hours. He is now doing better in his studies and in social settings. As his therapy progresses, he hopes to achieve a more balanced lifestyle. “I genuinely want to get better, to take pleasure in my life as it is and to love only the people who are part of my life and deserve my affection,” he says. ■



Eric Taipale is a freelance science writer based near Toronto, Canada. He mainly writes on subjects related to psychiatry and mental health

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Puzzles

Try our crossword, quick quiz and logic puzzle **p53**

Almost the last word

At what height do compasses stop working? **p54**

Tom Gauld for *New Scientist*

A cartoonist's take on the world **p55**

Feedback

Instagram scams and gifts from badgers: the week in weird **p56**

Twisteddoodles for *New Scientist*

Picturing the lighter side of life **p56**

Science with children

Beyond the bicarb volcano

Home-made science “experiments” are full of spectacle, but often miss the joy of true discovery. **Alom Shaha** offers a simple solution



Alom Shaha is a physics teacher at a comprehensive school, and author of books including *Mr Shaha's Recipes for Wonder*. Follow him @alomshaha

What you need

At least 50 ml of vinegar

At least one teaspoon of bicarbonate of soda

A measuring jug

An empty 500 ml plastic drink bottle

A funnel

A balloon

A teaspoon

I AM a science teacher and I think anyone who spends time with young children can be one too. It is in the home that children first encounter literature, maths, music and art – through reading, counting, singing and drawing. But this sort of informal teaching isn't so common when it comes to science. That is partly because many people lack the knowledge or confidence to talk about science with children, and partly because science isn't ingrained in our culture in quite the same way.

Some children do try out “experiments” at home, such as making a “volcano” using bicarbonate of soda, vinegar and washing-up liquid. Mixing bicarb with vinegar results in a chemical reaction that produces carbon dioxide gas. The gas forms bubbles in the washing-up liquid, causing foam to flow out of the container. This delights children but, for me, the real joy is in their realisation that they can make sense of what is happening using the idea that everything is made of atoms and that these can be rearranged, a bit like pieces of Lego.

In this case, I would tell children we are starting with four types of atom – sodium, carbon, hydrogen and oxygen – joined together in different ways to make sodium bicarbonate (NaHCO_3) and the molecules of ethanoic acid (CH_3COOH) found in vinegar. When these two chemicals come together, the molecules bump into each other and end up rearranged into new substances: carbon dioxide (CO_2), water (H_2O) and



SHUTTERSTOCK/BANGKOK CLICK STUDIO

sodium acetate ($\text{C}_2\text{H}_3\text{NaO}_2$).

Although this reaction is easy to do at home, it isn't much of an experiment. Instructions for activities like it are commonplace and tend to consist of directions for recreating entertaining phenomena. However, these guides often miss a key aspect of science: asking questions and trying to find the answers.

Instead of using the bicarbonate of soda and vinegar reaction to make a volcano, you could build a balloon-inflation machine to investigate factors that affect how much gas the reaction produces.

To do this, use a measuring jug to pour 50 millilitres of vinegar into an empty bottle. Then place a funnel into the mouth of a balloon and pour in a level teaspoon of bicarbonate of soda.

Stretch the mouth of the balloon over the open end of the bottle to form an airtight seal, taking care not to let any of the bicarb fall into the vinegar. When you are ready, lift the end of the balloon to mix the reactants.

As you are doing this, try asking questions like “what do you think will happen?”. Perhaps talk about how a solid and liquid are reacting to produce a gas. To turn this activity into an experiment, you could ask “how could we make the balloon even bigger?” You might even investigate what other liquids react with bicarbonate of soda and whether they have anything in common. ■

Next week

Science of cooking

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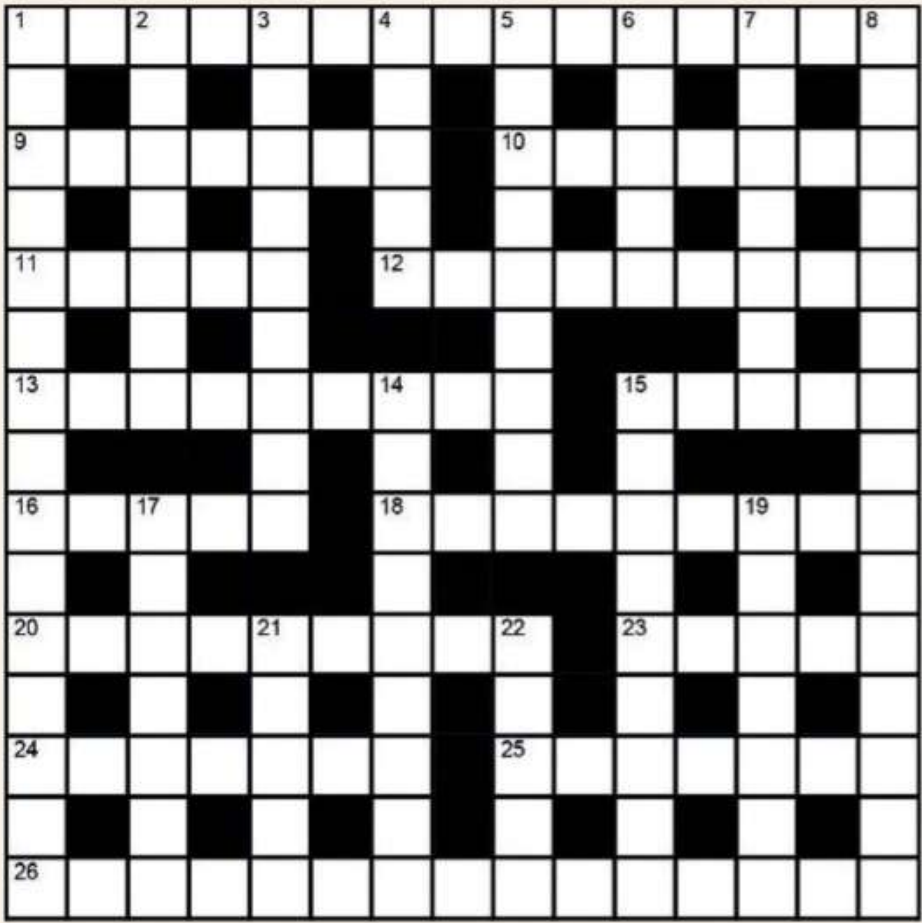
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Quick crossword #113 Set by Richard Smyth



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

- 1 1968 sci-fi adventure film starring Charlton Heston (6,2,3,4)
- 9 Disease in children, caused by a herpes virus (7)
- 10 Italian firearms firm founded in the 16th century (7)
- 11 Goat-like mammal of Asia (5)
- 12 N_0 (5-4)
- 13 Large water body mostly or entirely cut off from the oceans (6,3)
- 15 Bright star in the constellation Cygnus (5)
- 16 The smallest number that is neither prime nor semiprime (5)
- 18 Space explorer (9)
- 20 Before birth (9)
- 23 Concerned with ears and hearing (5)
- 24 Niche; cavity (7)
- 25 Hollow digestive organ (7)
- 26 Concept in game theory (4,1 1)

DOWN

- 1 Bird of prey, capable of flying at 320 kilometres per hour (9,6)
- 2 Southern (7)
- 3 Large astronomical body beyond our solar system (9)
- 4 City that is home to United States Strategic Command (5)
- 5 NaCl, when served with food (5,4)
- 6 The pale blue dot (5)
- 7 Regularity in design, mathematics or science, for example (7)
- 8 Orchid also known as "king of the angraecums" (4,2,9)
- 14 Windows user interface (5,4)
- 15 Deploy an explosive weapon from an aircraft (4,1,4)
- 17 Waste-water ducts (7)
- 19 Commercial aeroplane used for short flights (3,4)
- 21 Unwanted or meaningless sound (5)
- 22 US disinfectant brand (5)



Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #162

- 1 Shergotty, Nakhla and Chassigny all originated on which planet?
- 2 What name is given to the outermost membrane around the embryo in birds, mammals and reptiles?
- 3 Which geological period is named after the Latin word for Wales?
- 4 How many fundamental particles are there in the standard model of physics?
- 5 Where in the body would you find chondrocytes?

Answers on page 55

Puzzle

set by Peter Rowlett
#178 Hydra



A story: A hero enters a cave. Inside is a monster with three numbered heads. It attacks! Our hero chops off a head, but two more heads grow in its place. One of the new heads attacks and the hero greets it with a quick chop, too. Standing back, he realises that every chop produces at least one prime-numbered head that, when multiplied by the number on the other new head, gives the number from the head that was chopped. He also notices that all the prime-numbered heads are friendly.

The story's illustrator squints at the author's scribbled notes. She can make out the number on two of the original three heads, but not the third. Reading ahead, she notices that when the hero collapses triumphant at the feet of the now fully friendly monster, all the heads show different numbers and their sum is 113. "Aha!" she declares, and draws the original monster with its three snarling, numbered heads. What was the third number?

Solution next week

Hiccup hiatus

Holding your breath while pinching your nose is supposed to stop hiccups, but does anything actually cure hiccups?

Liz Reuben

Canberra, Australia

As a child, I was taught that hiccups were an effect of the diaphragm being in spasm. I find swallowing multiple small sips of water usually brings hiccups to an end within a few minutes.

I have no idea if this is because of some effect I am creating or some kind of learned response, but it consistently works.

Martin van Raay

Culemborg, The Netherlands

A hiccup is an involuntary contraction of the diaphragm. As the diaphragm is a muscle, and a voluntary one at that, the cure I have found that works best, if you have a bout of the hiccups, is to take a deep breath and hold

“I came across a hiccup cure 30 years ago and have never seen it fail. May it serve you as well as it has served me”

it for as long as you can, while tensioning your diaphragm.

To put it simply: show your diaphragm who is in charge. In my experience, you have to do this twice at most and the hiccups will be over.

Martin Andrews

Dundee, UK

A nun in the convent school my mother attended used to stop hiccups very quickly by applying finger pressure to the phrenic nerve, which controls the diaphragm, where it crosses the collarbone.

My mother used to perform this technique on me and my siblings when we were young too. The only problem is locating the exact spot to press.



This week's new questions

Unravelling words If you wrote a word on a ball of string, then unravelled it, how challenging would it be to decipher the word? *Howard Owens, Exeter, Devon, UK*

Breathe out We hear about the overload of carbon dioxide in the atmosphere, but what percentage of this comes from human exhalation? *Paul Gallagher, Devizes, Wiltshire, UK*

ANTON STARIKOV/ALAMY

Pete Champ

Rickmansworth, Hertfordshire, UK

Fill a pint glass to the brim with water. Drink continuously from the far side of the rim (so the glass tips away from you as you drink) until about three-quarters of the water is gone. I have no idea why, but it always works for me!

Leda Schubert

Plainfield, Vermont, US

The following technique has never failed me. Have someone stand behind you and place their hands over your ears. Simultaneously, both of you take a deep breath and hold it as long as you can. Release breath and ears. Hiccups gone!

Allison Swales

Chippenham, Wiltshire, UK

A tot of Benedictine liqueur

sipped slowly always cures my chronic hiccups.

Greg Harris

Abu Dhabi, United Arab Emirates

I came across the following hiccup cure about 30 years ago in a newspaper. In the intervening decades, I have never seen it fail. Take the deepest breath you possibly can, and hold it for around 10 seconds. Without exhaling, drink a full 12 ounce (about 350 millilitres) glass of water, then exhale and breathe normally. May it serve you as well as it has me. I would love to know why it works – can that be next week's question?

[Ed: Thank you to the many readers who sent in their variations of these hiccup cures]

How hard would it be to work out what was written on a ball of string, if it was unravelled?

Pointing up

At what height do navigation compasses stop working?

Mike Follows

Sutton Coldfield, West Midlands, UK

A compass needle is essentially a thin bar magnet. If it were free to move in all three dimensions, a magnet would line up along any local magnetic field line. Field lines are graphical representations of the strength and direction of the magnetic field in a region of space.

In principle, a navigation compass will work anywhere there are magnetic fields (which exist throughout the universe), although this doesn't guarantee that it would be helpful as a navigational aid.

Earth's magnetic field, the magnetosphere, extends to at least two or three times the radius of the planet and is limited by the influence of the solar wind.

Using a compass for navigation on the surface of Earth has its problems, particularly at the poles or if you switch between the hemispheres.

The compass needle is suspended on a tiny plinth. From side-on, this looks like a miniature see-saw. It is immersed in a transparent fluid, usually oil, to cushion the delicate mechanism from shock and dampen the movement of the needle.

The field lines are almost parallel to Earth's surface at the equator and are inclined to Earth's surface at an angle that increases with latitude until they are almost perpendicular to Earth's surface at the poles.

This means that, in the northern hemisphere, the north end of the needle will dip downwards (and the south end will rise up). But navigators are taught to hold map and compass horizontally and, to ensure that the needle is free to swing in the horizontal plane, a weight



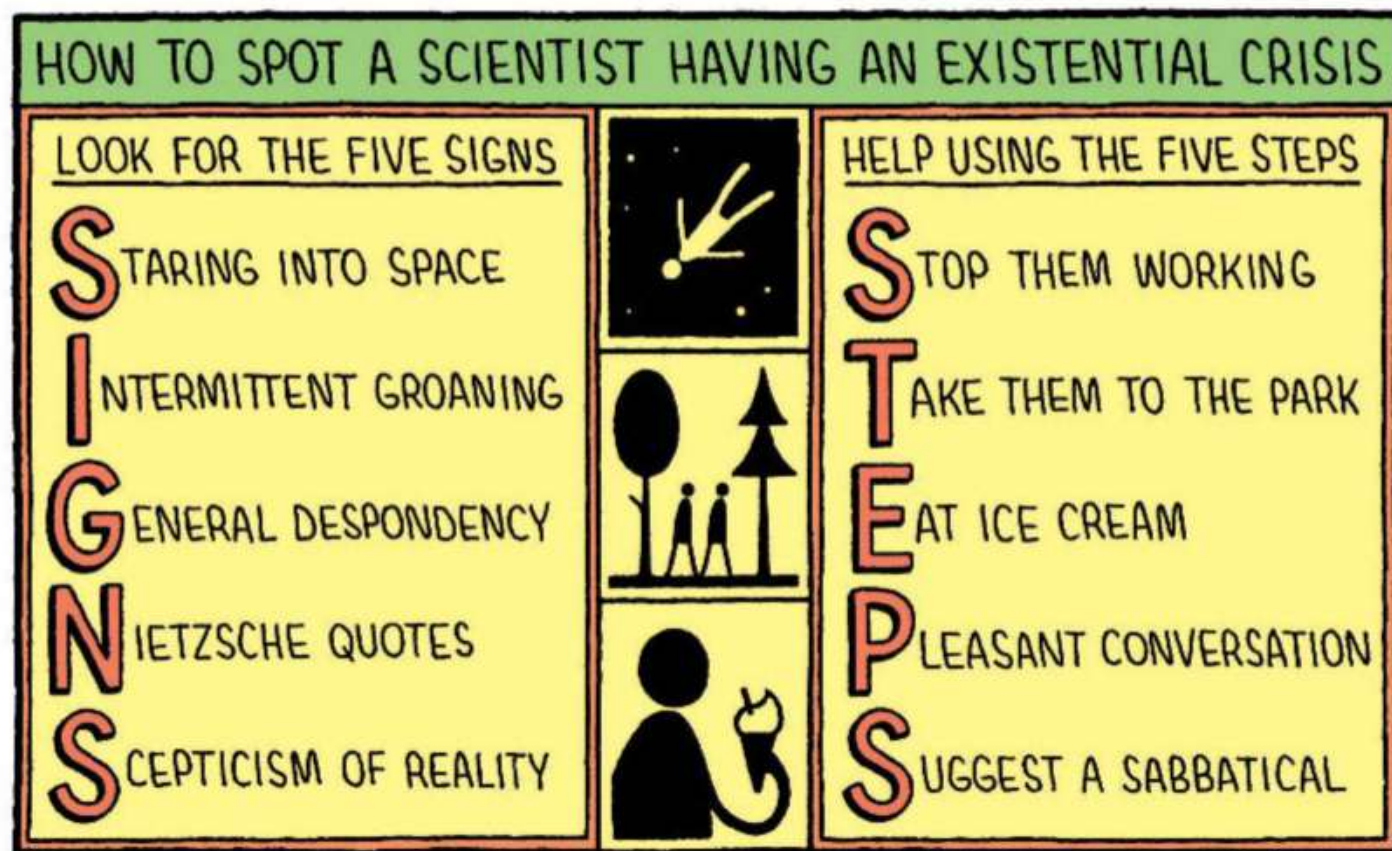
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Tom Gauld
for *New Scientist*



is added to the south side. This means that a compass designed for use in the northern hemisphere shouldn't be used in the southern hemisphere and vice versa.

The dipping of the needle is one of the reasons why magnetic compasses are next to useless at the poles and why the Vikings resorted to other navigation aids, probably including the use of Iceland spar. These crystals can be used to detect the polarisation of sunlight and infer the position of the sun even just after sunset.

Nippy nippers

Why do little children run everywhere instead of walking? Is it a legacy of sabre-toothed predators? (continued)

Ibrahim Gasim Ibrahim

Ahfad University for Women,
Omdurman, Sudan

When humans evolved into full bipeds, they would be constantly on the move. As there was no birth control, mothers would have

“Using a compass for navigation has its problems, particularly at the poles or if you switch between hemispheres”

several children in tandem. The result was that, as families grew larger, the younger members of the group would have to run to avoid being left behind – or so they believed.

This trend of running and chasing the older members of the child's group stuck with modern humans. Thus, most children today will run and chase around believing they need to catch up.

Toby Pereira

Rayne, Essex, UK

One reason not mentioned in previous answers (2 July) is that smaller animals (including little children) are more agile than larger ones because of the cube-square law.

In simple terms, as animals grow, you would expect their

mass to increase in proportion to the cube of their linear dimensions (such as length or height). But the cross-sectional area of their legs (a proxy for leg strength) would only increase in proportion to the square of their linear dimensions.

This would result in a deficit of leg strength in larger animals, so, in reality, they don't scale up proportionally in this way, and larger animals have relatively thicker legs.

But this all comes at a cost. In the ensuing trade-off, larger animals tend to be less agile than smaller ones, and running becomes more of an effort. Little children don't need big, muscly legs in order to run everywhere easily, whereas adults do.

Tony Chabot

Birmingham, UK

It is relatively easy to balance a metre rule on a finger, yet a pencil similarly balanced requires small, rapid adjustments. Perhaps small children run so they don't fall. ■

Answers

Quick quiz #162 Answers

- 1 Mars. They are asteroids that have reached Earth
- 2 The chorion
- 3 The Cambrian
- 4 17
- 5 Cartilage

Cryptic crossword #88 Answers

ACROSS 1 Rockery, 5 Theta, 8 Bidet, 9 Refract, 10 Bergamot, 11 Firm, 13 Plaice, 15 Hornet, 17 Rhea, 18 Chessmen, 21 I ask you, 22 Elder, 24 Ensur, 25 Hydrate

DOWN 1 Rub, 2 Coder, 3 Entrance, 4 Yarrow, 5 Tiff, 6 Elation, 7 Automaton, 10 Bipartite, 12 Hogshead, 14 Asepsis, 16 Thrush, 19 Media, 20 Dyne, 23 Roe

#177 Monkeying around Solution

Male and female *Equalis* monkeys have the same average number of brothers as each other. Although females in all-female families have no brothers, this is balanced out by mixed families that have at least one male, where females have more brothers.

More surprisingly, male and female *Fraternis* monkeys will also have the same number of brothers as each other, on average. In fact, this is true regardless of the ratio of males to females, even if 99 per cent of offspring are male. Of course, as the proportion of males grows, the average number of brothers also grows (for males and females).

Thought police

Maintaining China's 73-year ban on pornography is a job of work, but a natty new piece of headgear may help. The government's "porn appraisers" have now merely to cast their eyes over suspect material at speed, and their caps – a sort of wire-covered shower cap developed by researchers at Beijing Jiaotong University – will read their brainwaves and detect when something catches their salacious interest. *PC Gamer* wonders why the system is so far only 80 per cent accurate, suspecting it is because the training material comes pre-censored. But what if the erroneous results were false positives? Feedback is reminded of Tom Lehrer: "When correctly viewed, Everything is lewd..."

More to the point, perhaps the technology could be adapted to expedite Feedback's examination of the weekly inbox? One feels the gap between "Phwoar!" and "Woah!" must be largely semantic.

With friends like these...

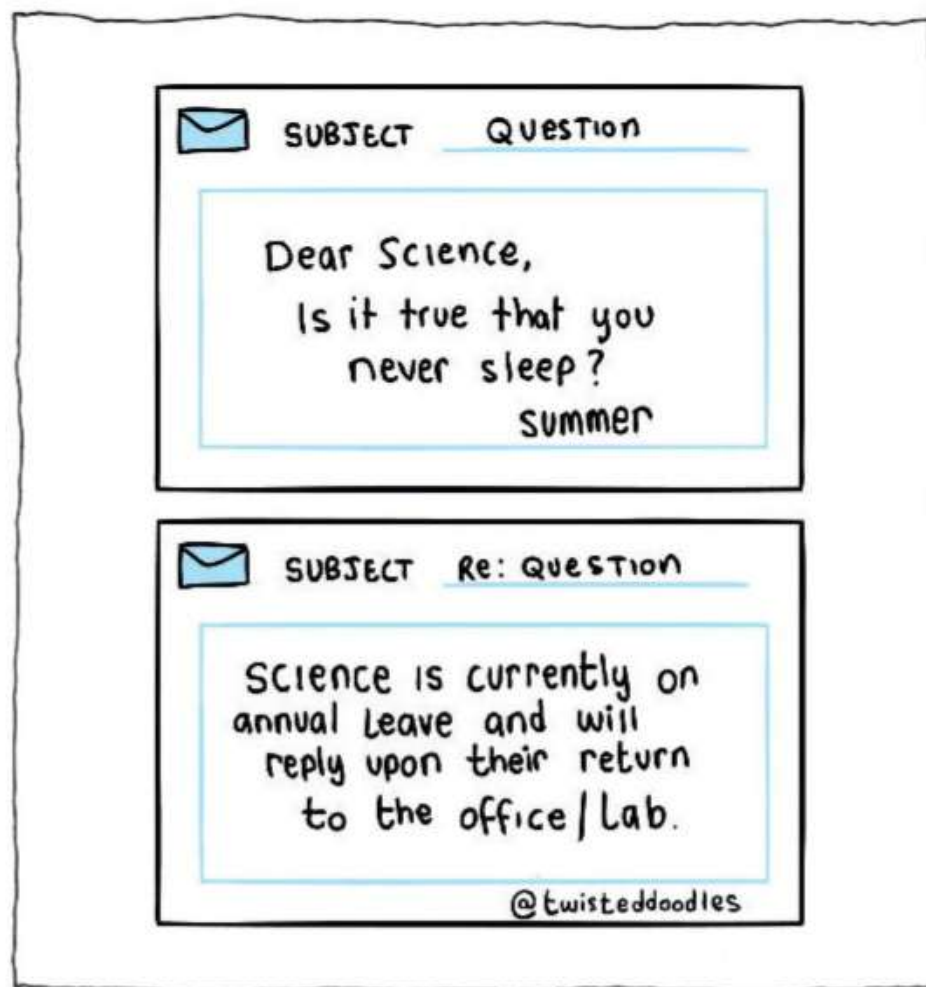
Spare a thought for Frank Tumwebaze, Uganda's minister of agriculture, animal industry and fisheries. His government is trying to encourage the African diaspora to invest, and who better to sing his country's praises than Hollywood star Terrence Howard. So Tumwebaze invited him.

Not only did Howard turn up in Uganda with a "new hydrogen technology", he also announced he "was able to identify the grand unified field equation they've been looking for, and put it into geometry". Goodness! "We're talking about unlimited bonding, unlimited predictable structures, super symmetry," he went on. Plenty for Uganda to mull over.

Bad influence

They strike poses, dance to music and trample crops. So far, so like the faerie folk of Feedback's childhood (we were young once). But this lot also stirs up unmanageable crowds

Twisteddoodles for New Scientist



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Consideration of items sent in the post will be delayed

that block traffic and so, reports tech news site Rest of World, Nepal's tourism authorities have called time on TikTok's influencers and banned them from key sites.

"Making TikTok by playing loud music creates a nuisance for pilgrims from all over the world who come to the birthplace of Gautama Buddha," says a spokesperson.

It isn't just the pilgrimage sites being overrun: chamomile farmers have had to harvest early because TikTokers were gambolling about in their precious crop.

Specious copy

Psychics and tarot readers have been spreading like wildfire across Instagram (a land of faerie and wyrd if ever there was one). Instagramming "intuitives" have found up to 15 copies of themselves on the site, as sprites

(or "scammers", as Motherboard unimaginatively dubs them) copy accounts and try to trick their victims' clients into paying them for services.

For a tarot reader to cry fraud raises a cool smile in these quarters. That said, let us agree that getting between someone and their next meal is Not Cool. Now, @opulentwitch is organising a metaphysical ceremony to protect her colleagues from scammers. More pragmatically, tarot reader Nova Magick has set up a Scammer Alert Page.

Blushes all around

The forces of wyrd are no respecters of intellectual property. Shortly after sunset on 20 July, fans of *Stranger Things* were disconcerted to find the sky to the west of Mildura, in north-west

Victoria, Australia, filled by the TV show's signature bilious pink glow.

According to party poopers at *The Guardian*, this harbinger of the Upside Down actually emanated from a nearby medicinal cannabis facility that had omitted to close its blinds. (Pink light encourages cannabis plants to bud.) Which was all a bit embarrassing for the Cann Group, which was supposed to be keeping the location of its facility a secret – and no comfort at all for fans of the show, for whom talk of secret facilities in rural locations carries a disquieting significance.

Bones to pick

Horror of a more contained sort visited Dudley resident Ann Mathers, according to a local BBC report. The sudden appearance of a skull in her garden brought the police round, and a steady supply of human remains followed. Badgers have been fetching these unwanted gifts from a nearby cemetery – but why? There are urgent calls for the alley they have been using to be shut off, before they reveal their darker purpose.

Covid corral

The uncanny continues: reader Richard Hind gets a well-deserved sugar lump for spying an odd entry in the list of "21 Covid symptoms you should know about" in the *News and Star of Cumbria*. At number 16: "Horse voice". And there we were, thinking the good folk of north-west England had herd immunity.

Ring of fire

Puns like that really ought to trigger some sort of Lloyd's of London bell – and we now know who should ring it. Paul Wood, a resident of Hamilton, New Zealand, writes to tell us that a campanologist at his Māori church was one Rongo Bell. This being too good to be true, Paul investigated further: in Māori, *rongo* means "listen". At which point Feedback's brainwave-reading shower cap caught fire. ■



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